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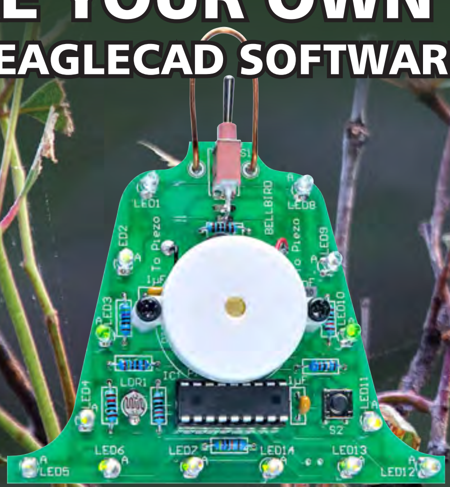

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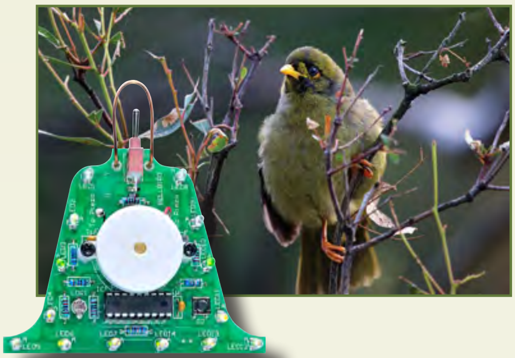

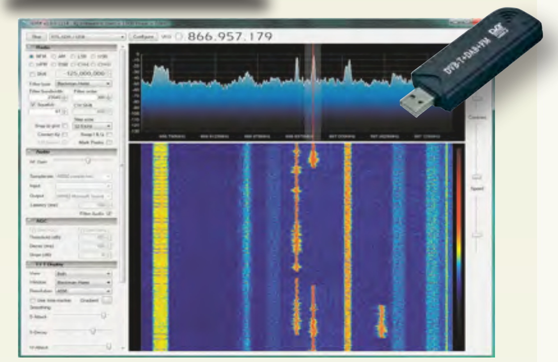

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Our January 2015 issue will be published on Thursday 04 December 2014, see page 72 for details.

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EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip Remote Control Demo Board with ZENA™ Wireless Adapter (part No. DM240315-2). This kit integrates Graphics, mTouch, USB, and RF4CE into a single demo board. The board demonstrates a remote control populated with PIC24FJ256DA210 MCU, 3.5-inch Graphical TFT LCD with resistive touch screen, capacitive touch keys with plastic overlay, MRF24J40 2.4GHz transceiver and ZENA™ Wireless Adapter, a multi-function USB wireless adapter connecting USB-equipped desktops or notebook computers with Microchip wireless products for development or application uses.

KEY FEATURES:
● Integrates Graphics, mTouch, USB and RF4CE ● User Interface with colorful 3.5-inch QVGA graphical display, resistive touch screen and mTouch keys ● Low-cost graphics and high integration with PIC24F "DA" family ● Simple hardware layout ● MRF24J40MA – 2.4GHz IEEE 802.15.4 radio transceiver ● ZENA™ Wireless Adapter ● Wireless Remote Control Utility that runs on the target computer

AUG 2014 ISSUE WINNERS
Geoff Weetman who works at Ampcontrol UK Ltd
Malcolm Gale who works at JME Ltd
Paul Cooper who is a Retired Engineer
They all won a Microchip a Low Pin Count USB Development Kit each valued at £24.00.

HOW TO ENTER

For the chance to win a Microchip Remote Control Demo Board with ZENA Wireless Adapter, visit **http://www.microchip-comps.com/epe-wazena** and enter your details in the online entry form

CLOSING DATE

The closing date for this offer is 31 December 2014

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EVERYDAY PRACTICAL ELECTRONICS

Another slice of Pi?

No doubt about it, one of my favourite reads in *EPE* over the last year was *Teach-In 2014*; Mike Tooley's in-depth look at the Raspberry Pi computer. Therefore, I'm delighted that Mike has agreed to serve up just a little more of everyone's favourite soft fruit dish. We start this month with a comprehensive review of an excellent analogue-to-digital board designed for the Pi, and Mike has promised reviews of two more useful boards in upcoming issues. Even more exciting is the news that next month he'll provide a comprehensive look at the latest Pi model, the B+. (If you need a quick look at the details of this update then do read *Interface* in this issue – Robert Penfold has provided us with a succinct early look.)

Teach-In 2015

…but wait, there is even more from the Tooleys! From February 2015 we will start on our next *Teach-In* series – yes, you guessed it, to be called *Teach-In 2015*. After the digital fun and games of 2014 we will go back to basics with key analogue fundamentals in 2015 – plenty to look forward to.

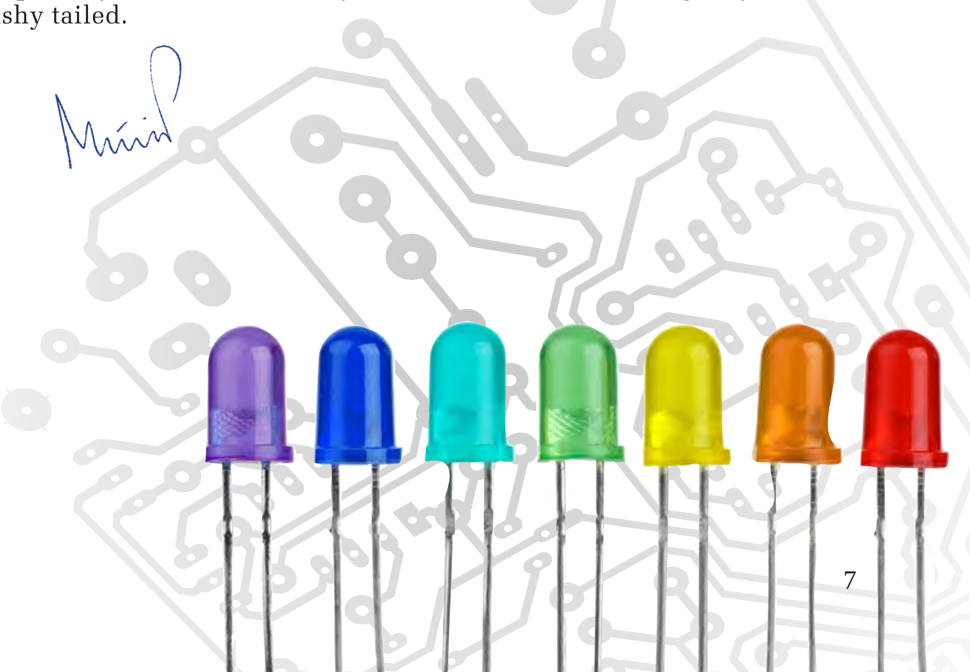
Soldering Guide published

Readers will be interested to know that Alan Winstanley's *The Basic Soldering Guide Handbook* has now been published in a new full-colour paperback. Sponsored by Antex Electronics, the 86-page book is available from your local Amazon site or direct from Createspace in the USA (**https://www.createspace.com/4905655**). You can also download it in Kindle format for free (Amazon Prime users only). More details and links are provided at: **www.epemag.com/resources.html**.

If you fancy publishing your own treatise on electronics-related material then do keep an eye on upcoming *Net Work* pages. Alan will be examining some routes to self-publishing in a forthcoming *Net Work* column.

Audio Out and Cool Beans

Are you missing your monthly serving of *Audio Out* and *Cool Beans*? – fear not, they will be back next month. We had so much to cram into this issue that a couple of our regular columns had to stand aside temporarily – rest assured, they will return next month bright eyed and bushy tailed.



NEWS

A roundup of the latest Everyday News from the world of electronics

Berlin Spy Stories – report by Barry Fox

Spy snoops are always at the cutting edge of technology. Berlin was a divided city and a hotbed for espionage until 1990. This has created opportunities to see historic spy tech from both sides of the Cold War Iron Curtain; but the opportunities are not well publicised.

Stasi Museum

In early 1990, soon after the infamous Berlin Wall came down, Berliners stormed the headquarters of the hated Stasi, the Ministry for State Security's secret police, and the office of head man Erich Mielke. The crowd's mission was to prevent the destruction of the 111 kilometres of paper files, 1.7 million photos and 28,000 recordings, which the Stasi had accumulated over 40 years, and feared would be used as evidence against them.

The crowd partly succeeded in saving the contents, and later the utility concrete building (on Ruschestrasse) later became the Stasi Museum with some fascinating examples of early spy technology. But explanation of the exhibits was sketchy and mostly in German. The Museum is now closed for improvement and should re-open again in 2015 – hopefully with more and better information in English for world visitors.

There are politically correct 'discotheque regulations' for 'music propagandist' disc jockeys playing LPs made by communist state record company Amiga. I still have one, which I bought in East Berlin while the city was divided; it was pressed from very poor quality vinyl and sounds like sandpaper.

Listening to Western radio or watching Western TV was forbidden, but hard to control because the Wall could not stop radio waves. Colour TV was watchable in monochrome.

East German radios were biased towards East European stations – Warsaw, Moscow, Prague...

There are apocryphal stories of East Berlin school teachers trying to trick children into revealing what their parents were watching, by asking the class to draw the TV test card they saw on their home TV. Stasi office staff were given domestic valve radios, with marks on the dial for approved East German radio stations.

Stasi chairs were designed to capture samples of body smell when an unsuspecting suspect was invited to sit down. Samples were bottled and used to set dogs on the trail of the suspects after they left the building.

Cameras

The museum has many spy cameras, with large film roll containers for automated shooting over long surveillance periods, often with early infra-red illuminators for night vision.

Before the crowd stormed the building the Stasi staff desperately tried to destroy their large stock of everyday objects, which had been modified to hold hidden cameras and recorders. The remains remain – for instance, an innocent-looking Thermos flask houses a small camera.

Totschka was a miniature camera based on a Minox; it was worn by the KGB to take pictures through a tie pin. The Tessina camea was made in Switzerland and hidden in a shopping bag, to take pictures through a hollow rivet. A sub-miniature Tessina was small enough to hide in a wallet, with the lens seeing out through a perforation in the pocket for coins.

Hugely powerful infra-red radiators were hidden behind plastic panels of a car door, to illuminate surveillance targets. Cal-Zeiss-Jena developed an autofocus camera for the Stasi. It used a laser rangefinder and with infra-red lighting had a range for night photography of 20 metres. The system cost a huge 215,000 Marks and even the Stasi could only afford to commission 25 of them.

Secret recorders

Recorders were built into industrial strength bodies. Microphones were hidden in hollow railway track

sleepers. Bugs were put inside telephone sockets and junction boxes to monitor calls. Power for the bugs came from the telephone line, while an FM transmitter working on frequencies between 940 and 980MHz beamed the bugged conversation to a Stasi snooper 100m away.

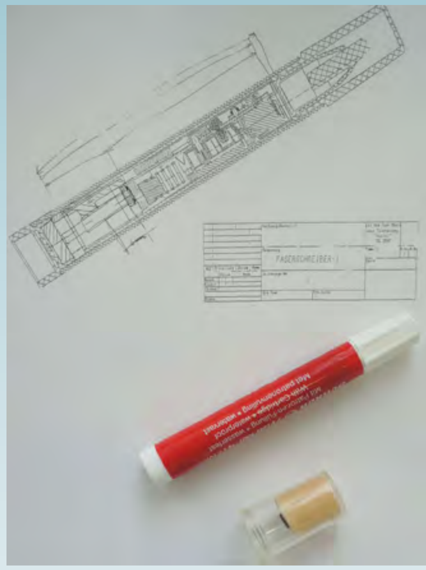
Infra-red surveillance radiators hidden in a plastic car panel

Pencil rods with a microphone in the tip were poked through holes in the wall to feed Swiss Nagra miniature reel-to-reel tape recorders. The same recorders were concealed under an agent's clothing and fed by a microphone hidden in a wrist watch.

The Stasi also bought Memocord recorders made by their sworn enemies in West Germany.

Towards the end of their reign, the Stasi developed infra-red flash guns which were hidden in shoulder bags to take covert shots at night or in low light. The camera and flash were controlled by decorative buttons on the bag, which held pressure switches.

By 1989, Carl-Zeiss-Jena was secretly making ten marker pens, with miniature cameras hidden inside the stubby stick bodies. The plan was to give them to Erich Mielke as a show of technological strength. But the wall came down and Mielke was gone before he saw them. They are still there at Ruschestrasse.



An East German Zeiss camera hidden inside a West German Pelikan marker pen

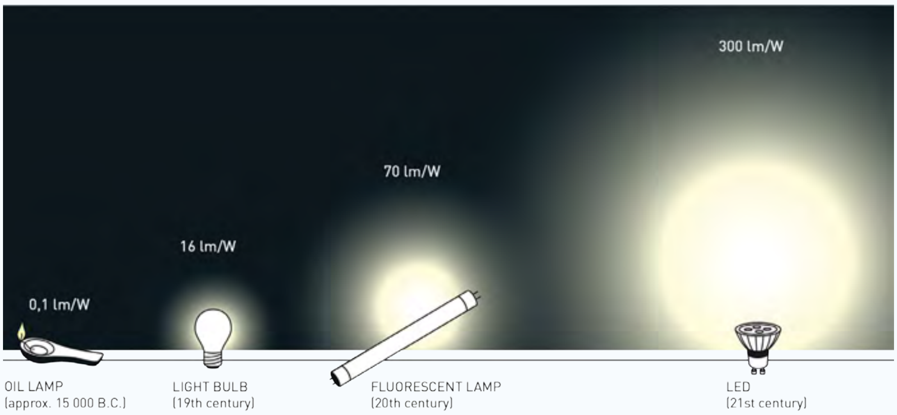
Next month, I will tell how it's now possible to get inside the high-tech spy radio and radar station built by the American National Security Agency (NSA) to spy on East German communications traffic.

Blue is the winner!

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2014 to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura 'for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources'.

In the spirit of Alfred Nobel the Prize rewards an invention of greatest benefit to mankind; using blue LEDs, white light can be created in a new way. When the inventors produced bright blue light beams from their semi-conductors in the early 1990s, they triggered a fundamental transformation of lighting technology. Red and green diodes had been around for a long time but without blue light, white lamps could not be created – the blue LED had remained a challenge for three decades, but they succeeded where everyone else had failed. Their inventions were revolutionary. Incandescent lighting lit the 20th century; the 21st century will be lit by LEDs.

White LED lamps are long-lasting and energy-efficient. They are constantly improved, getting more efficient with higher luminous flux (measured in lumen) per unit electrical input power (watts). The most recent record is just over 300lm/W (16lm/W for regular light bulbs and 70lm/W for fluorescent lamps). One fourth of electricity consumption is used for lighting purposes, so the LEDs contribute to saving the Earth's resources. Materials consumption is also diminished because LEDs last up to 100,000 hours, compared to 1,000 for incandescent bulbs and 10,000 hours for fluorescent lights.



Light out vs energy in – image © Johan Jarnestad/The Royal Swedish Academy of Sciences

Sheffield computing tornado

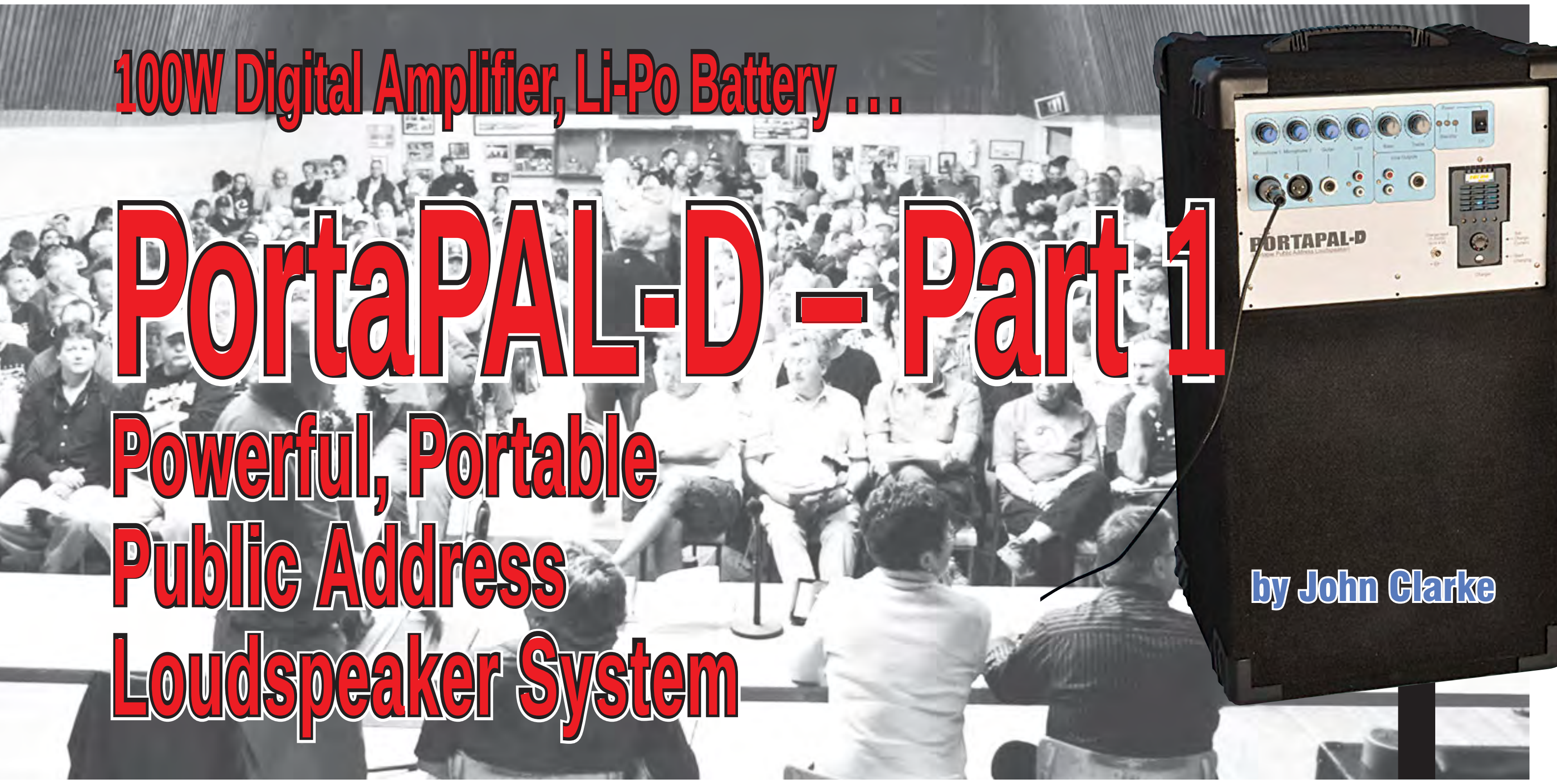
Computers of the future could be built from 'magnetic tornadoes', according to new research into nanotechnology at Sheffield University.

Magnetic materials form the basis of most hard disc drives, but now the team from the University's Faculty of Engineering has been investigating whether they could also take on the role of a CPU.

Using computer simulations, the team have shown it is possible to create magnetic 'logic gates', the fundamental building blocks of a CPU, using magnetic materials.

Dr Hayward says: 'In wires of magnetic material, two hundred times thinner than a human hair, magnetism can form into swirling 'tornadoes', known as magnetic vortex domain walls. In our simulations, we use vortices where the magnetism turns clockwise to represent 0 and vortices where it turns anticlockwise to represent 1, allowing us to encode binary data. The vortices are then flowed through the wires using, and interacted with, carefully defined features in the wires that recreate the function of logic gates.'

The researchers now plan to build experimental prototypes of the logic gates, and to investigate whether they can be made smaller and to operate faster – critical steps in developing the concept into a usable technology.



100W Digital Amplifier, Li-Po Battery . . .

PortaPAL-D – Part 1

Powerful, Portable Public Address Loudspeaker System

by John Clarke

With battery operation, high efficiency loudspeakers and a class-D amplifier, the PortaPAL-D PA system has enough power to blow your socks off! It's ideal for busking, sports events, meetings or anywhere you need a powerful, portable PA system.

While we have published other public address loudspeaker systems, we felt it was time for something that really used up-to-date ideas. For example, technology has marched ahead with efficient class-D amplifiers, along with the advent of lithium batteries, which are much more energy dense.

Our new *PortaPAL-D* uses the *CLASSiC-D Amplifier* published in November and December 2013, along with its matching speaker protector from the same months and the *DC-DC Converter* published in May 2014.

With that combination we have a high-power amplifier that can be run from a 12V battery. One year later, we have added the preamplifiers, mixer, tone controls and power supervision necessary for the *PortaPAL-D* to function properly.

We are using two 8Ω 200mm loudspeakers (with concentric tweeters) in parallel to handle the full 100W available from the amplifier. Buying the commercial equivalent could quite easily set you back more than five or six hundred pounds!

The *PortaPAL-D* is ruggedly housed in a timber cabinet measuring 620 × 350 × 330mm and weighing about 20kg. It is covered in speaker carpet with corner protectors, to guard against damage from bumps and roadie use.

The two loudspeakers are mounted behind protective steel grilles that are themselves protected by being recessed into the box.

On the rear is the main control panel, again recessed into the box for protection against damage.

A top hat socket, for use with a speaker stand and a carry handle are included.

The cabinet and chassis for the electronics can be made using standard tools. And you need not worry about small imperfections while building the cabinet since these will be covered by the carpet. The result will be a PA box that sounds great and looks professionally finished.

Sealed enclosure

The cabinet includes an open section to mount the *PortaPAL-D* electronics, but the rest of the box is an infinite baffle design. This has advantages over an open-back design in that the sealed cabinet provides damping of the speaker cone at low frequencies, preventing the cone from being overdriven with high-power bass signals (or when accidentally dropping a microphone onto the floor!).

Another advantage is that the microphone just needs to be positioned behind the front edge of the speaker cabinet to minimise acoustic feedback.

Two XLR sockets are provided for balanced microphones, with one channel providing phantom power, if required. Both inputs can be used with dynamic microphones. Guitar input is via a standard 6.35mm jack socket, while RCA stereo sockets mix left and right line inputs into a mono signal. Each input has its own level control; bass and treble tone controls are also provided.

PortaPAL-D features

- Class-D low-distortion power amplifier delivering up to 100W to the loudspeakers
- Portable 12V Li-Po battery-powered amplifier with charger
- Twin 200mm loudspeakers with integral tweeters
- Two microphone inputs (4.5mV)
- Guitar input (50mV)
- Line input (1V) and output
- Individual level controls
- Bass and treble controls
- Standby power-down to conserve battery power
- Low battery shutdown
- Standby indication
- Charger indication
- Thermostat-operated air circulation fan
- Rugged cabinet with carpet, corner protectors and speaker grilles
- Top hat included for use with speaker stands

A line output is provided to feed an additional amplifier or recorder.

Power source and management

The *PortaPAL-D* is powered by a 12V lithium polymer (Li-Po) battery rather than a sealed lead acid (SLA) type.

This makes it much lighter. While a typical 7.2Ah SLA battery will weigh 2.55kg, the much smaller 8Ah Li-Po is less than a third of this. Plus, the Li-Po battery can be discharged much more deeply before recharging. In effect, you get more than double the SLA's capacity for a fraction of the weight and size.

As well as a main power switch, a two-stage standby circuit automatically powers down sections of the circuit to reduce power drain if the *PortaPAL-D* is not making noise. Two LED indicators show the standby status. Power is restored quickly when an input signal is detected.

A low-battery shutdown is also included, which protects the battery from over-discharge. We estimate that the *PortaPAL-D* should run for at least eight hours with normal use and longer with periods of shutdown.

A commercially-made charger (intended for Li-Po cells) is set into the front panel, so that its controls can be accessed and its status LED visible. This can be powered from a nominal 12V (11-15V) supply, with a current up to 4.5A if the supply can deliver that.

The battery can be charged at any time, regardless of whether the *PortaPAL-D* is in use or even switched off.

Typically, a 12V plugpack would be used to charge the *PortaPAL-D*, although a larger battery could be used, either free-standing or in a vehicle.

Circuit overview

Fig.1 shows the general arrangement of the *PortaPAL-D*. As already mentioned, we use the *CLASSiC-D Amplifier* module, the loudspeaker protector and the *DC-DC Converter* published previously. Full details for these projects can be found in the November and December 2013 issues for the amplifier and protector and the May 2014 issue for the *DC-DC Converter*.

The *CLASSiC-D Amplifier* is used mainly due to its efficiency (and therefore power saving). It can run at high power without generating too much heat. This is a distinct advantage

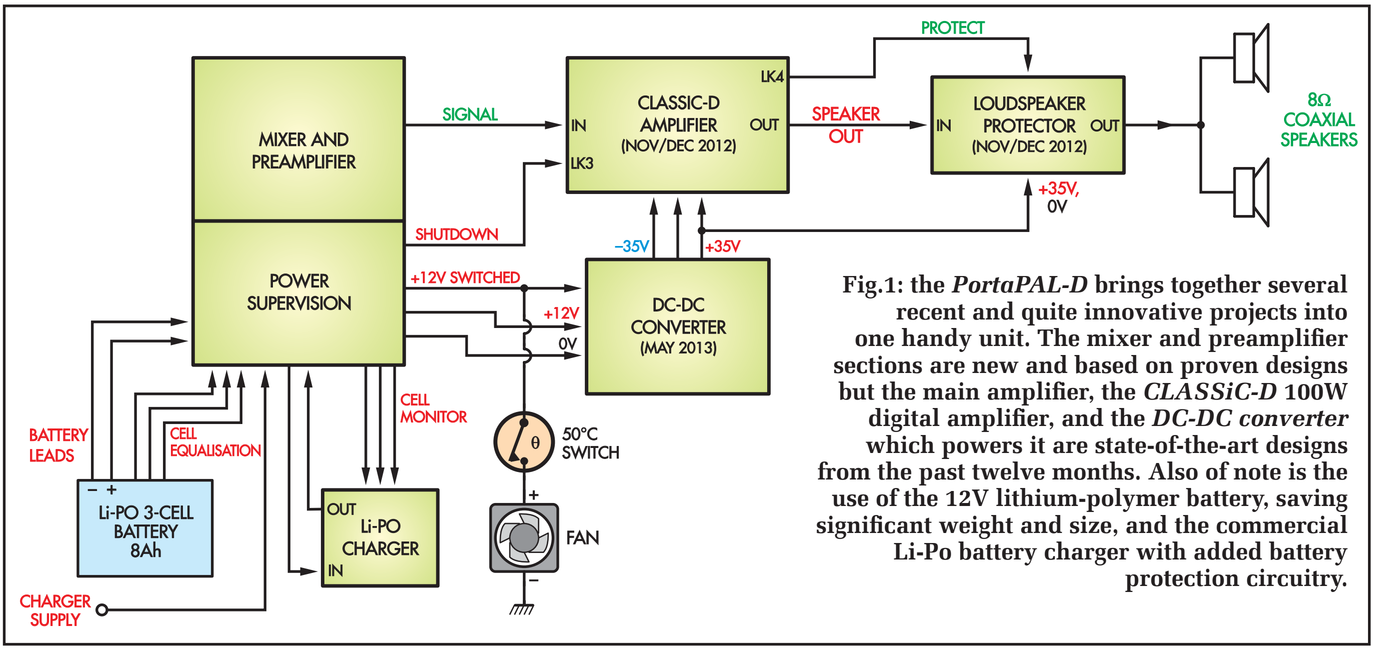


Fig.1: the *PortaPAL-D* brings together several recent and quite innovative projects into one handy unit. The mixer and preamplifier sections are new and based on proven designs but the main amplifier, the *CLASSiC-D* 100W digital amplifier, and the *DC-DC converter* which powers it are state-of-the-art designs from the past twelve months. Also of note is the use of the 12V lithium-polymer battery, saving significant weight and size, and the commercial Li-Po battery charger with added battery protection circuitry.

over conventional class-AB amplifiers, which are nowhere near as efficient and generate significant heat.

Another reason is that the amplifier has proven reliable and has low levels of distortion and noise with extra features such as temperature cut out and over-current protection.

The *CLASSiC-D Amplifier* is powered by a *DC-DC converter*, delivering ±35V DC supply from a 12V supply. With this, it can supply up to 100W into 4Ω for short periods and 50W on a continuous basis.

A small fan is switched by a thermostat when the amplifier heatsink reaches 50°C, circulating cooling air.

Battery-saving auto shutdown

To conserve battery energy when not actually being driven, the *PortaPAL-D* has a two-stage shutdown.

First, after a short period of no signal, the amplifier module is shut down. This is controlled in part by the power supervision section. In the second stage, after a longer period of no signal, the power supervision circuitry switches off the *DC-DC Converter* and so powers down the system.

The power supervision circuitry also controls the charging of the battery. While power is applied, the charger continually measures the voltage of each cell, ensuring each is not over- or under-charged.

Typically, the lithium-polymer cell balancing leads would connect directly to the charger. However, this could mean the cells would discharge via the charger over time and possibly flatten the battery. To avoid this, we connect

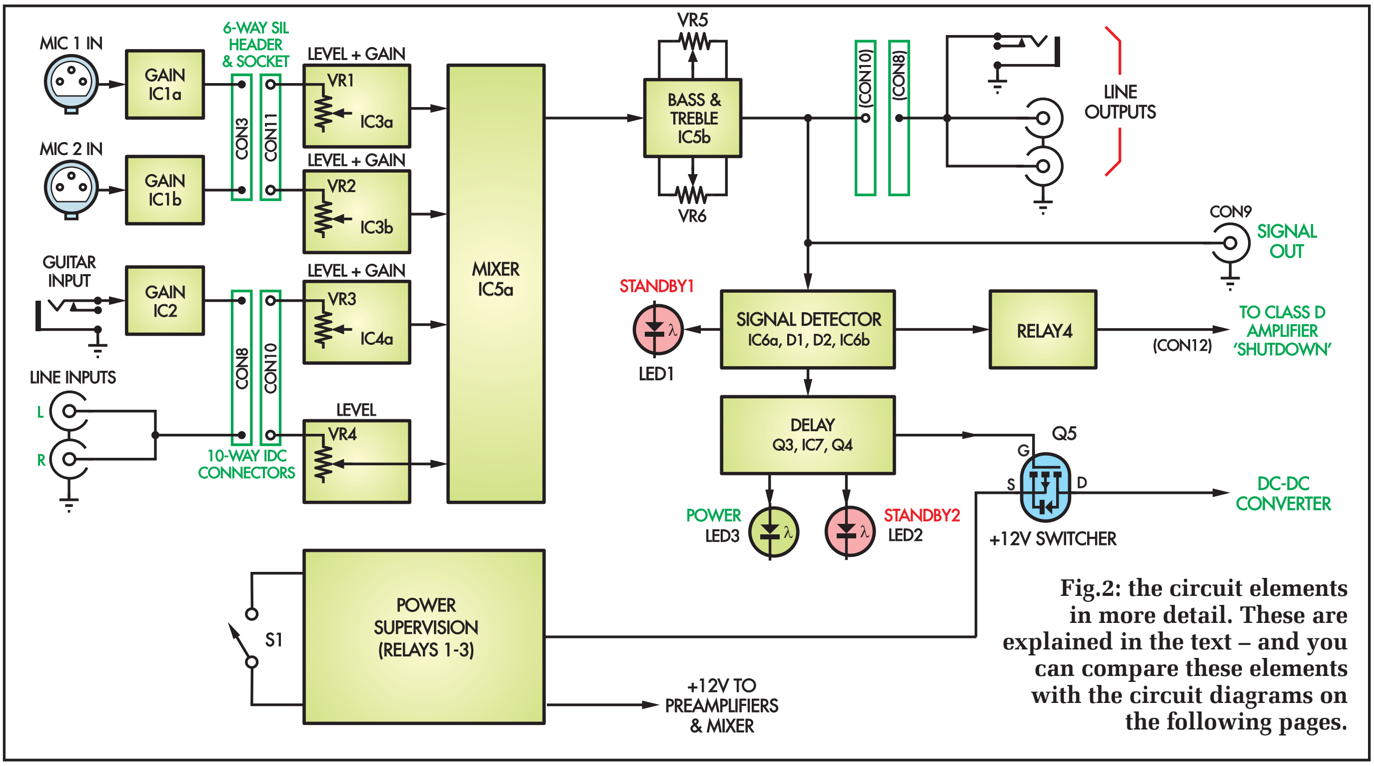


Fig.2: the circuit elements in more detail. These are explained in the text – and you can compare these elements with the circuit diagrams on the following pages.

the cell monitor leads via the power supervision circuitry.

Details of the preamplifier, mixer and standby circuitry are shown in Fig.2. Microphone inputs (Mic1 and Mic2) and their gain stages (IC1a and IC1b) are on their own PCB and connect to the main PCB via a 6-way single in line (SIL) header and socket. The guitar input and line input plus the line outputs are also on a separate PCB and similarly connect via a 10-way IDC socket and plug.

The level potentiometers control the gain, with additional gain provided after the level controls for the microphone and guitar inputs. A mixer combines the four signals (Mic1, Mic2, Guitar and Line) and its output is fed to the bass and treble tone controls. From there the signal goes to the input for the *CLASSiC-D Amplifier*, to the line outputs and also to a signal detector, which forms part of the shutdown circuitry.

In 'Standby 1' state, if the signal is off for longer than 15s, relay 4 is triggered, shutting down the *CLASSiC-D Amplifier*. The *Amplifier* is still powered, but in shutdown. LED1 lights to show this state. Any input signal will instantly restore full operation to the amplifier.

If there is still no input signal after about 100s, 'Standby2' state is entered. Power is switched off to the *DC-DC Converter* and this in turn switches off the *CLASSiC-D Amplifier*, while LED2 lights – indicating Standby 2. When there is audio, power is restored to the amplifier within one second. LED3 lights to show power is on.

PortaPAL-D specifications

Output Power	100W into 4Ω short term 50W into 4Ω continuous
Output sound level	Typically 96dB (SPL) at 1W
Input sensitivity and Frequency fesponse (–3dB)	Microphone: 4.5mV; <20Hz-20kHz Guitar: 50mV; 25Hz-25kHz Line: 1V; <20Hz-50kHz
Tone controls	Bass +11dB and –14dB at 100Hz Treble +9.5dB and –12.6dB at 10kHz
Signal-to-noise ratio	–80dB with respect to 50W into 4Ω (inputs at minimum gain; 20Hz-20kHz bandwidth)
Muting	Threshold at <150mW output power
Standby modes (no input)	15s typical for Standby1 100s typical for Standby2 <1s return to normal operation
Battery consumption	'Low battery' state activated – 8.5μA Standby2 – 45mA (DC-DC converter turned off) Standby1 – 320mA (amplifier only turned off) Powered, before either standby state – 730mA
'Low Battery' thresholds	Typically 10.5V switches PortaPAL-D off 11.2V switches PortaPAL-D on
Battery charger	Input 11-15VDC, 4.5A charging current maximum
Dimensions	620 x 350 x 330mm inclusive of corner protectors
Mass	17.5kg

Here's a view of the electronics module in its metalwork, removed from the *PortaPAL-D* speaker box. A commercial charger is incorporated because it is perfectly suited to the Li-Po battery pack we used and will result in longest battery life.

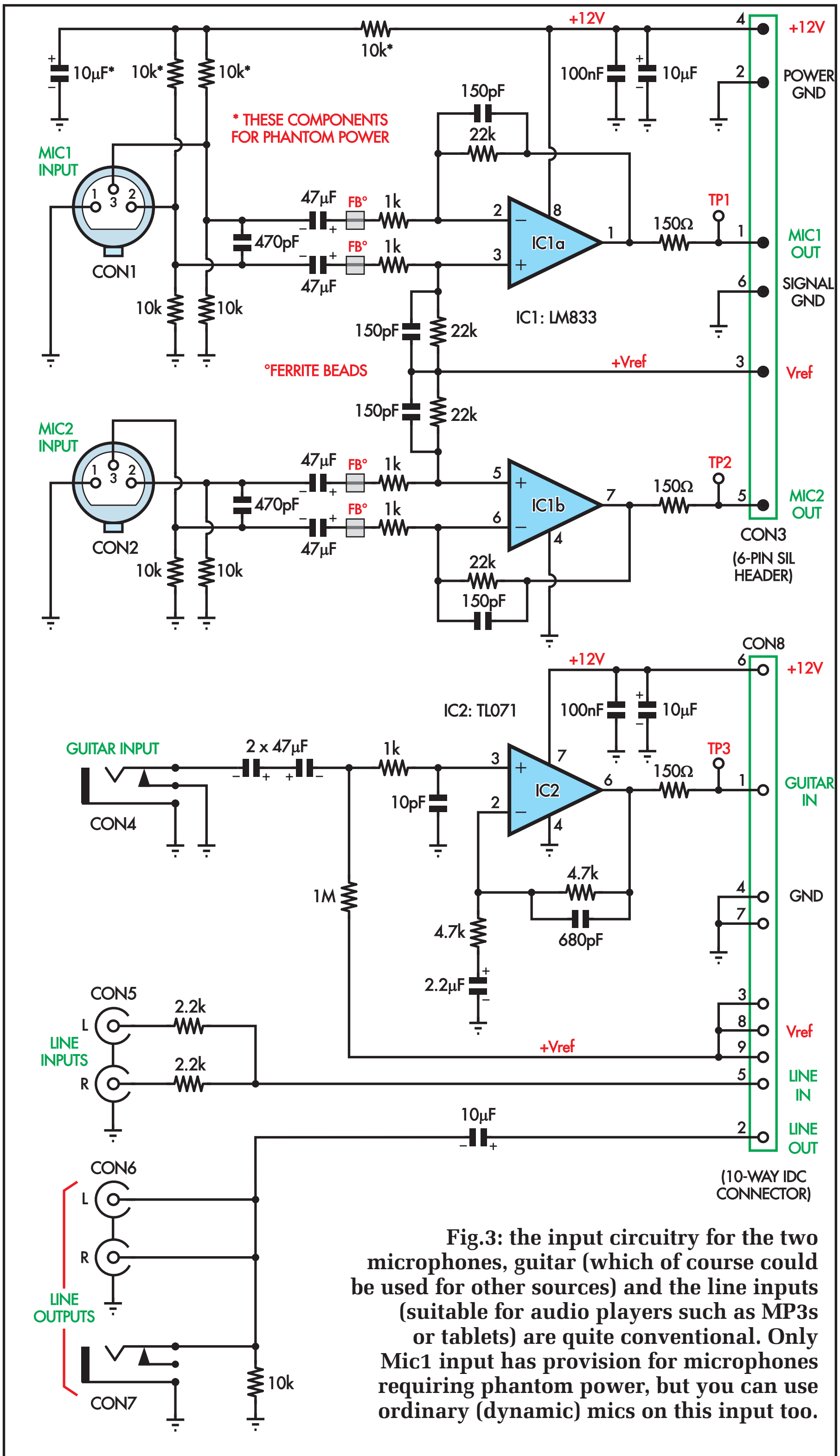
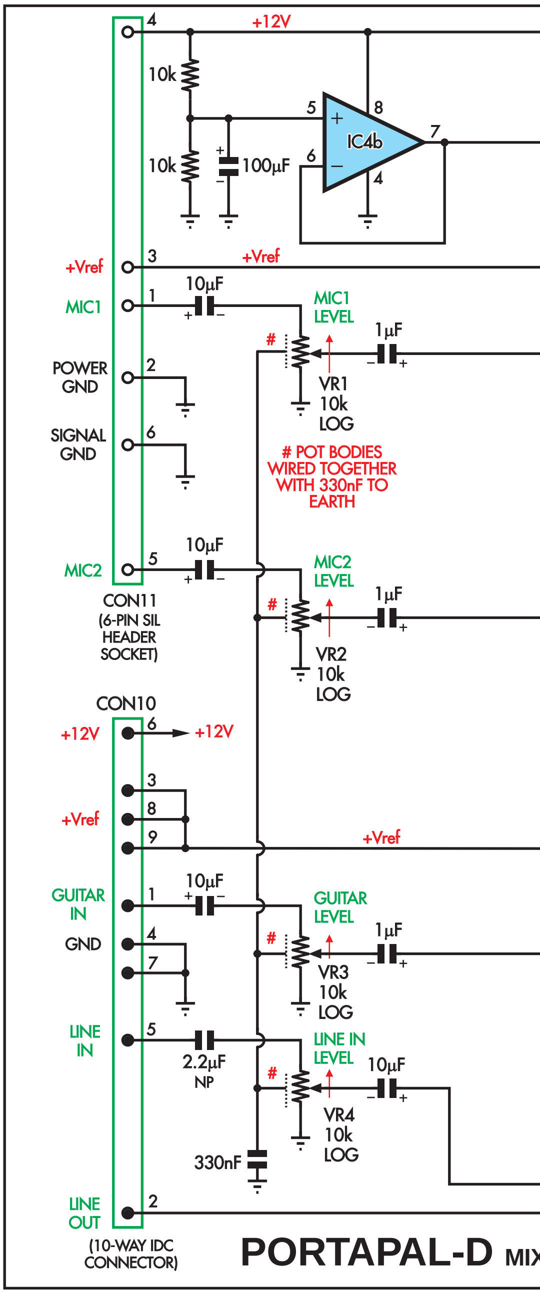


Fig.3: the input circuitry for the two microphones, guitar (which of course could be used for other sources) and the line inputs (suitable for audio players such as MP3s or tablets) are quite conventional. Only Mic1 input has provision for microphones requiring phantom power, but you can use ordinary (dynamic) mics on this input too.

PORTAPAL-D MICROPHONE, GUITAR & LINE INPUTS AND OUTPUTS



Main power is controlled via switch S1. If on, the battery voltage is monitored by the low voltage shutdown section (IC8 and Q1).

Should the battery supply drop below about 10.5V, the power to the preamplifiers and mixer is removed and the whole system shuts down. Current draw is only that of the low voltage shutdown circuitry at 8.5µA.

Circuit detail

Balanced microphone inputs for Mic1 and Mic2 are via XLR sockets, with the signals fed to the inputs of low noise op amps IC1a and IC1b. Assuming 600Ω microphones, these preamplifiers have a gain of 22. Both are identical, except that the Mic1 input provides phantom power for electret microphones (if used).

Phantom power is limited to 0.5mA or so, sufficient for the typical electret microphones used in PA systems but not condenser microphones. If more current is required, reduce the 10kΩ resistors, possibly to 2.2kΩ or less.

High frequencies above 48kHz are rolled off by the 150pF capacitors across the 22kΩ feedback resistors. The 470pF capacitor shunting the balanced input lines, in conjunction with the

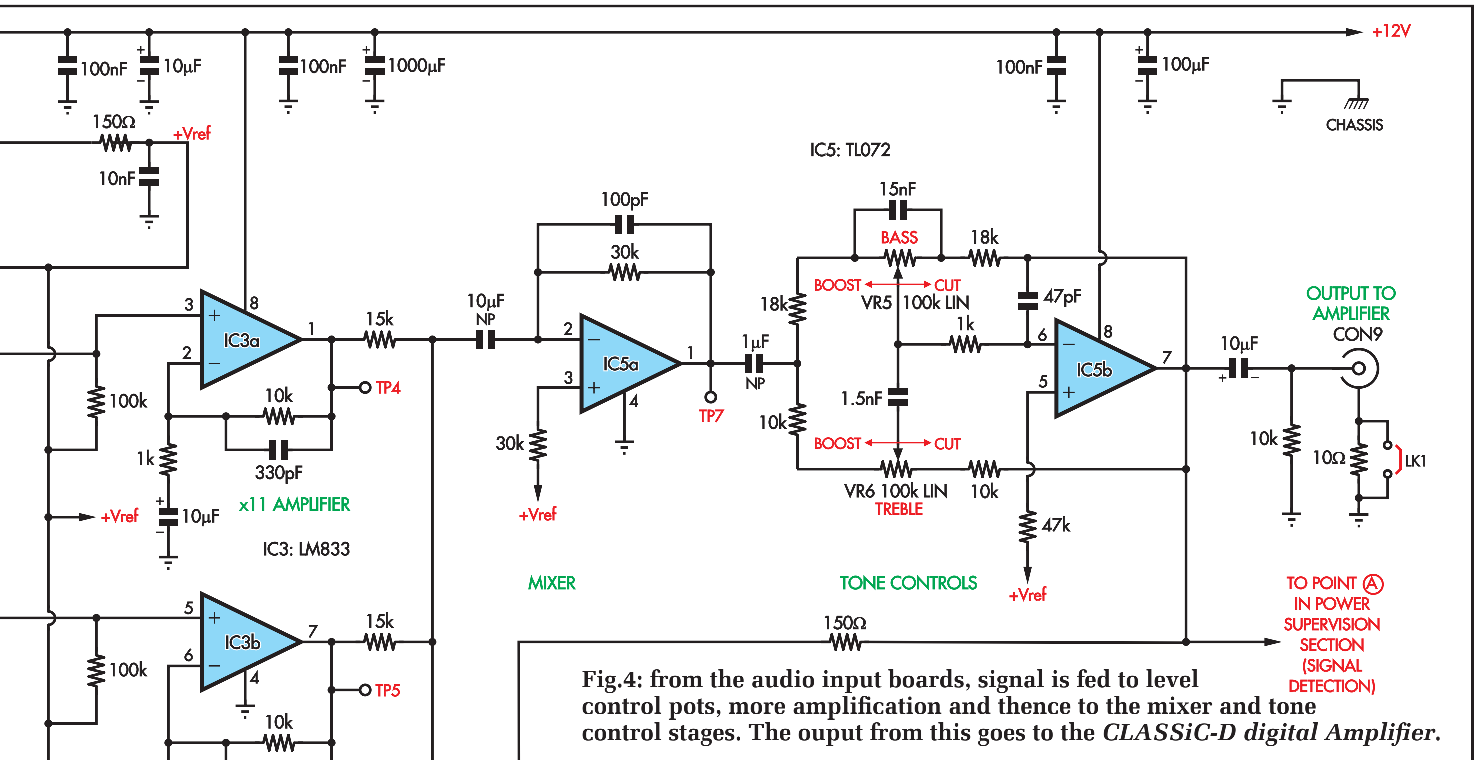
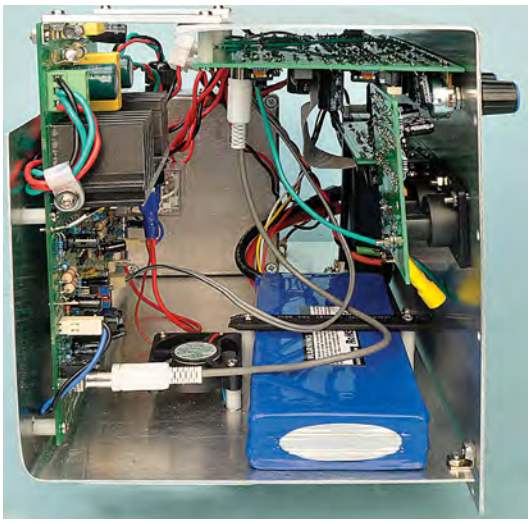


Fig.4: from the audio input boards, signal is fed to level control pots, more amplification and thence to the mixer and tone control stages. The ouput from this goes to the ***CLASSiC-D digital Amplifier*****.**



To whet your appetite ready for the assembly details next month, this shot shows the internal make-up of the ***PortaPAL-D*****. At left (vertical) is the main** ***CLASSiC-D Amplifier*** **board, while at top right is the mixer and tone control PCB. Below that is the mic, guitar and line input/ output board, while the long blue object is the Li-Po battery. Its charger is the 'black box' almost hidden at rear, along with the** ***DC-DC Converter*** **in its own diecast case.**

microphone impedance, also roll off the high frequencies.

Ferrite beads in the 1kΩ input resistors help to reduce RF pickup, while the use of 1% resistors in the balanced microphone circuits ensures good rejection of common-mode signals such as mains hum.

The unbalanced outputs are each fed to level potentiometers VR1 and VR2 via a 150Ω stopper resistor and 10µF AC coupling capacitor. The signals are then applied to op amps IC3a and IC3b, both of which have a gain of 11. This means that the maximum value of gain for microphone signals before the mixer is 242.

Guitar input

The guitar input stage comprises IC2, a TL071 FET-input op amp connected as a non-inverting amplifier with a gain of two for mid-band frequencies.

The guitar signal is coupled via two 47µF capacitors in series. These are equivalent to a non-polarised capacitor and are included to cater for inputs with a positive or negative bias voltage, that goes beyond the voltage bias set by the Vref (at half supply).

We have specified the high load resistance of 1MΩ to ensure optimum high frequency response with the relatively high inductance of typical guitar pickups. With such a high load resistance, you might wonder why we have used such a large input coupling capacitance. After all, to maintain a flat response to below 20Hz, all you need is an 8.2nF input capacitor. The reason is to minimise noise, which occurs when op amp IC2 sees as low a source impedance as possible.

Output from IC2 is coupled to the 'guitar' level control, VR3, via a 150Ω resistor and 10µF capacitor. The signal is then fed to op amp IC4a, which is identical to IC3a and IC3b.

Line signal

Stereo line inputs (eg, from a CD player or MP3 player) are mixed to a

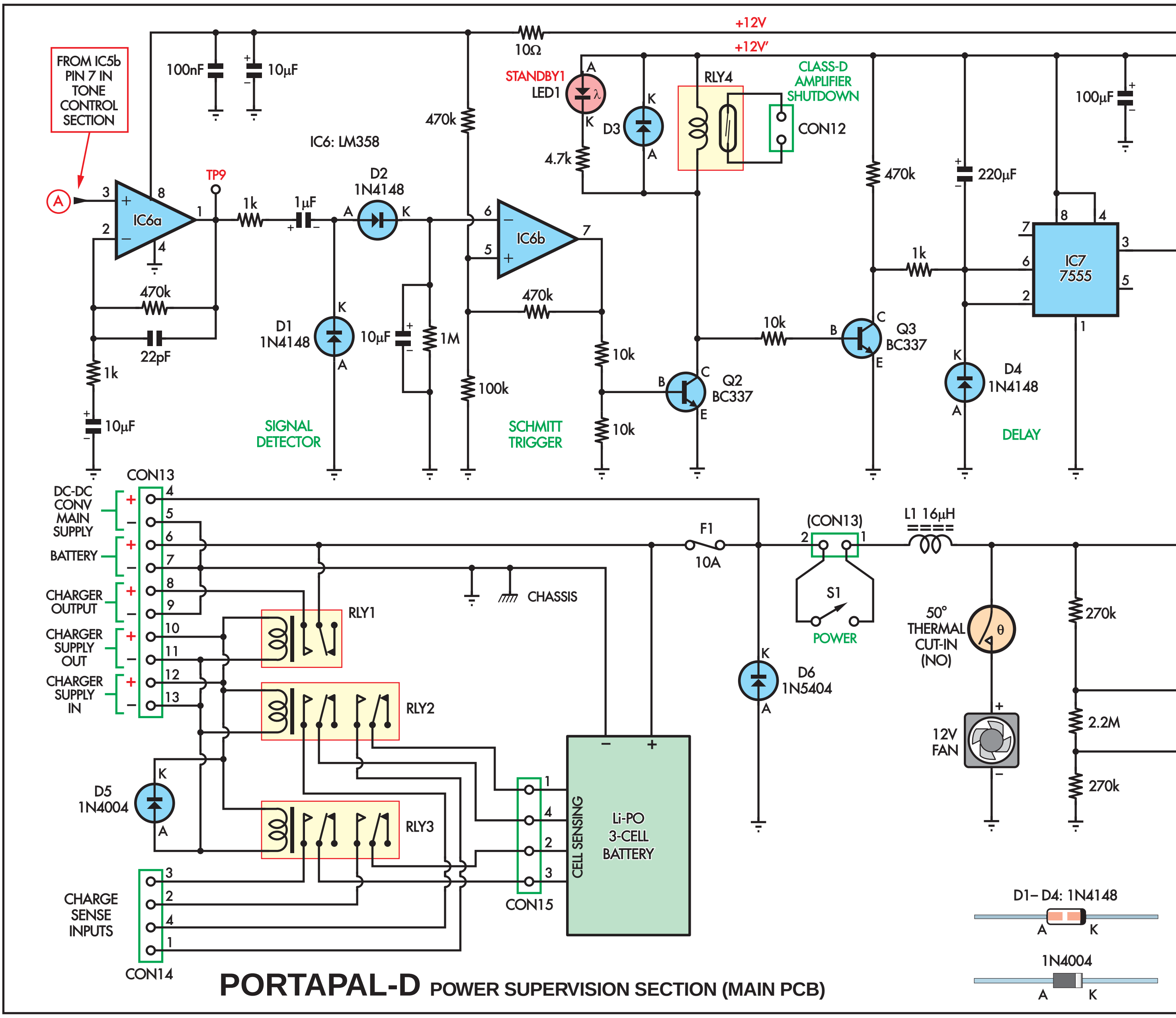


Fig.5: here's where the *PortaPAL-D* excels over earlier mixer designs – it uses a Li-Po battery and a commercial charger to give much more 'bang for buck' when it comes to portable use. For a full explanation, see the accompanying text.

mono signal with 2.2kΩ resistors and fed to potentiometer VR4 via a 2.2µF coupling capacitor.

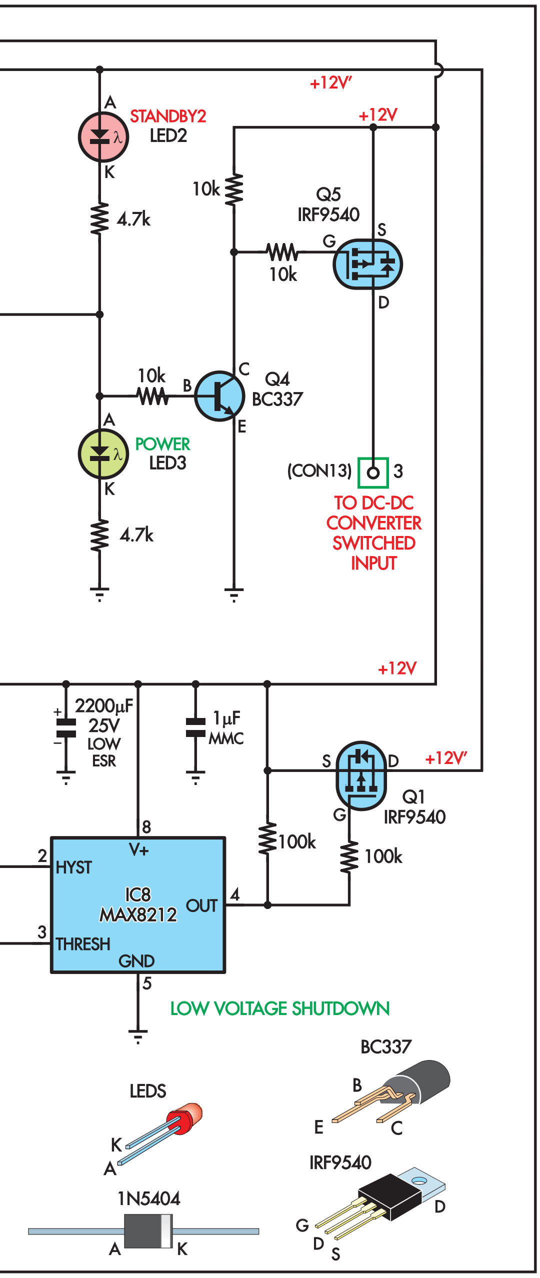
Signals from all four input sources are mixed via 15kΩ resistors for the mic and guitar signals, and a 10kΩ resistor for the line signal in inverting amplifier IC5a. This has a gain of minus two for the first mic and guitar signals, with slightly higher gain for the line input signals (due to the 10kΩ resistor to compensate for a slight gain loss in the resistive mixing of the stereo line inputs).

IC5a drives the tone control stage comprising IC5b, VR5 and VR6 and associated resistors and capacitors. IC5b's output signal is fed to three separate places: the line output via RCA and 6.35mm jack sockets; the signal detection stages involving IC6a; and the input to the *CLASSiC-D Power Amplifier*.

All of the op amps in the circuit used as signal amplifiers are biased via the Vref line, which is at half supply (about +6V). This is derived from the +12V line by a voltage divider consisting of two 10kΩ resistors with the centre point bypassed by a 100µF capacitor. The bypassed supply is then buffered by op amp IC4b to provide the Vref line. All these biased op amp outputs will sit at about half the battery voltage, with the audio signal rising and falling about this DC voltage.

Shutdown

As noted above, we have incorporated signal detection into the circuit to shut down the power amplifier in order to reduce current consumption when no signal is present. Op amp IC6a is a non-inverting amplifier with a gain of 471, set by the 470kΩ and 1kΩ feedback resistors. The 22pF capacitor rolls the gain off above 15kHz, while the 10µF capacitor in series with the 1kΩ resistor rolls off signals below 15Hz.



The amplified signal from IC6a is then fed to a diode pump circuit consisting of diodes D1 and D2 and the 1µF and 10µF capacitors connected to them. The peak level of the signal from IC6a will be stored in the 10µF capacitor, which is continuously but slowly discharged via the 1MΩ resistor across it.

IC6b, connected as a Schmitt trigger inverter, monitors this voltage. A 470kΩ resistor between pin 5 and pin 7 applies positive feedback to give hysteresis. This makes the comparator output switch cleanly between high and low, and prevents oscillation at the switching threshold. The inverting input of IC6b is set at +2.1V (ignoring the effect of the 470kΩ feedback resistor) using the 470kΩ and 100kΩ resistors across the 12V supply.

When power is first applied to the circuit, the 10µF capacitor between the 12V supply and the inverting input to IC6b is initially discharged and therefore pulls pin 6 low, causing the output (pin 7) to be high. This turns on transistor Q2, so relay 4's contacts close and the *CLASSiC-D Amplifier* is shut down.

At the same time, transistor Q3 is turned off, so IC7's inputs (pins 2 and 6) are high due to the 220µF capacitor connecting to the 12V supply being initially discharged. The output (pin 3) is low, so Standby 2 LED (LED2) is lit. The low output holds both Q4 off and MOSFET Q5 off. This removes power from the *DC-DC Converter* switch and as a result the *CLASSiC-D Amplifier* is off.

When an audio signal is detected by IC6b, the input (pin 6) will go above the 2.1V at pin 5 so the output (pin 7) goes low, switching off Q2 and the relay. Diode D3 quenches the back-EMF of the collapsing relay coil field.

There is still a low current flow through the relay coil and Q3 – not enough to pull the relay in but enough to turn Q3 on. This provides a path to ground (via the 1kΩ resistor) which charges the 220µF capacitor.

The now-low input to the 7555 causes its output (pin 3) to go high, switching on the power LED (LED3) and transistor Q4 and switching off the Standby 2 LED. MOSFET Q5 also switches on and the *DC-DC Converter* is powered, in turn powering the *CLASSiC-D Amplifier*.

Low battery

Regardless of the battery type, it is important that it not be over-discharged and permanently damaged. While the lithium-polymers types used in the *PortaPAL-D* are better in this repect than SLAs, care still needs to be taken to avoid damage.

Low battery voltage is detected using IC8, a micropower voltage monitor that compares the voltage at pin 3 to an internal 1.15V reference. With a 12V supply, the voltage divider across IC8's input will ensure that pin 3 is always above 1.15V. However, as the battery discharges, this voltage will drop. Below 10.5V, IC8's output (pin 4) will go high, turning off MOSFET Q1. This removes power from the rest of the circuit, thus preventing the battery being discharged any further.

Pin 2 provides hysteresis, stopping the circuit oscillating back and forth around the 1.15V threshold. While the voltage at pin 3 stays above 1.15V, pin 2 is effectively connected to the supply rail, thus shorting out the 270kΩ resistor to 12V.

However, if the pin 3 voltage drops below 1.15V, then pin 2 is effectively open circuit. So that extra 270kΩ resistance is added to the voltage divider, which drops the voltage at pin 3 even lower (just over 1V with a 10.5V supply). Therefore, the battery needs to be charged to more than 11.6V before the output (pin 4) goes low, allowing the MOSFET to power the circuit again.

Power

Power from the battery passes through the 10A fuse, F1 and power switch S1. Inductor L1 and the 2200µF capacitor filter the supply, helping prevent *DC-DC Converter* switching noise from entering the supply for the audio op amps. Additional filtering is provided with the 10Ω resistor and the supply decoupling capacitors on the 12V rail.

Note that the high current supply required by the *DC-DC Converter* is tapped off before the switch. Only the low power switching current to control the *DC-DC Converter* is at the output to Q5.

Reverse polarity protection is via diode D6: this will blow the fuse if the supply polarity is inadvertently connected back to front.

Charging

Three relays are used to switch in the charger connections. The supply to the charger is tapped at pins 10-13 of CON13 so that when power is available, relays (Relay1, Relay2 and Relay3) will be switched on. The charger output is switched to the battery positive via relay 1 contacts while the cell balancing outputs from the battery are connected to the charger via relay 2 and relay 3 contacts.

When there is no power applied to the charger input, the relay contacts open and completely disconnect the charger from the battery.

PortaPAL-D – Parts List

Main PCB (Mixer and power supervision)

1 PCB available from the *EPE PCB Service*, coded 01111131, 212 × 100mm
1 10-way IDC PCB mount socket (CON10)
2 10-way IDC line plugs
1 100mm length of 10-way IDC cable
1 6-way SIL socket (CON11)
1 2-pin header, 2.54mm spacing (LK1)
1 2-pin polarised header, 2.54mm spacing (CON12)
2 2-way pin header sockets
1 jumper shunt
6 DIL8 IC sockets (optional)
2 M205 PCB fuse clips
1 M205 10A fast blow fuse (F1)
1 iron powdered toroid 28 × 14 × 11mm L1
5 2-way PCB mount screw connectors (5.08mm pin spacing) (CON13)
1 3-way PCB mount screw connectors (5.08mm pin spacing) (CON13)
1 vertical PCB mount RCA socket (CON9)
2 RCA line plugs
1 12V 10 or 16A SPDT relay (RELAY1)
2 12V 1A DPDT relays] Altronics S4150, Jaycar SY-4059] (RELAY2,RELAY3)
1 12V SPST DIL reed relay (RELAY4)
4 16mm single PCB mount 10kΩ log potentiometers and nuts (VR1-VR4)
2 16mm single PCB mount 100kΩ linear potentiometers and nuts (VR5,VR6)
6 knobs to suit above potentiometers (4 blue, 2 grey)
3 M3 tapped spacers 15mm long
1 solder lug
4 M3 × 10mm machine screws
2 M3 × 15mm machine screws
6 pot nuts (providing for an extra nut under potentiometer)
1 3S 250mm 2×JST-XH parallel balance lead [http://hobbyking.com.au/hobbyking/store/__32036__JST_XH_Parallel_Balance_Lead_3S_250mm_2xJST_XH_.html]
1 1.5m length of 1mm diam. enamelled copper wire for L1
1 150mm length of 7.5A rated green hookup wire
1 150mm length of single core screened cable
1 270mm twin figure-8 light gauge wire
1 190mm length of 0.7mm diam. tinned copper wire
1 100mm cable tie
2 PC stakes

Semiconductors
2 LM833 dual low noise op amps (IC3,IC4)
1 TL072 dual op amp (IC5)
1 LM358 dual op amp (IC6)
1 7555 CMOS 555 timer (IC7)
1 MAX8212 voltage monitor (IC8)
2 IRF9540 P-channel MOSFETs (Q1,Q5)
3 BC337 NPN transistors (Q2-Q4)
4 1N4148 diodes (D1-D4)
1 1N4004 1A diode (D5)
1 1N5404 3A diode (D6)
3 3mm high brightness LEDs (LED1 and 2 [red]; LED3 [green])

Capacitors
Electrolytic (PC type)
1 2200µF 25V low ESR
1 1000µF 16V 1 220µF 16V 3 100µF 16V 12 10µF 16V
1 10µF NP 50V 1 2.2µF NP 50V 4 1µF 16V 1 1µF 50V NP
MKT polyester
1 330nF 4 100nF 1 15nF 1 10nF 1 1.5nF
Ceramic
1 1µF monolithic multilayer (MMC)
3 330pF 1 100pF 1 47pF 1 22pF

Resistors (0.25W, 1%)
1 2.2MΩ 1 1MΩ 4 470kΩ 2 270kΩ 6 100kΩ
1 47kΩ 2 30kΩ 2 18kΩ 3 15kΩ 15 10kΩ
3 4.7kΩ 7 1kΩ 2 150Ω 2 10Ω

Guitar input, line input and output PCB

1 PCB available from the *EPE PCB Service*, coded 01111133, 109 × 35mm
2 PCB mount 6.35mm switched jack sockets (CON4,CON7)
2 stereo RCA vertical stacked PCB mount (CON5,CON6)
1 10-way IDC PCB mount socket (CON8)
1 DIL8 IC socket (optional)

Semiconductors
1 TL071 single op amp (IC2)

Capacitors
Electrolytic (PC type)
2 47µF 16V 2 10µF 16V 1 2.2µF 16V PC
1 100nF MKT polyester 1 680pF ceramic 1 10pF ceramic

Resistors (0.25W, 1%)
1 1MΩ 1 10kΩ 2 4.7kΩ 2 2.2kΩ 1 1kΩ 1 150Ω

Microphone input PCB

1 PCB available from the *EPE PCB Service*, coded 01111132, 64 × 73mm
2 PCB mount XLR female connectors (CON1,CON2)
1 right angle 6-way pin header with backing plate removed (CON3)
1 chassis mount 6.4mm spade terminal
1 female spade 6.4mm quick connector
4 ferrite beads 4mm ID × 5mm long
1 DIL8 IC socket (optional)
4 4g × 6mm self tapping screws or M3 × 6mm screws
1 M3 × 10mm machine screw
1 M3 nut
2 3mm star washers

Semiconductors
1 LM833 low noise dual op amp (IC1)

Capacitors
4 47µF 16V PC electrolytic 2 10µF 16V PC electrolytic
1 100nF MKT polyester 2 470pF ceramic
4 150pF ceramic

Resistors (0.25W, 1%)
4 22kΩ 7 10kΩ 4 1kΩ 2 150Ω

Extras

1 CLASSiC-D Amplifier set for a ±35V output (see *EPE* November and December 2013)
1 Loudspeaker Protector for the CLASSiC-D set for a 35V supply (see *EPE*, November/December 2013)
1 50°C NO thermostat
1 10µF 16V PC electrolytic capacitor (used in Loudspeaker Protector)
1 DC-DC Converter for the CLASSiC-D (see *EPE*, May 2014)
1 10kΩ 0.25W 1% resistor (used in DC-DC converter)
1 Li-Po 11.1V battery (ZIPPY Flightmax 8000mAh 3S1P 30C) (http://hobbyking.com.au/hobbyking/store/__19530__ZIPPY_Flightmax_8000mAh_3S1P_30C_AUS_Warehouse_.html
1 HobbyKing E4 Li-Po balance charger (http://hobbyking.com.au/hobbyking/store/__14633__HobbyKing_E4_Balance_Charger.html)
1 Polymax 5.5mm Gold Connector plug and socket set (http://hobbyking.com.au/hobbyking/store/uh_viewitem.asp?idproduct=18659)
1 strap handle
1 1.8m × 3m speaker box carpet
8 corner protectors
1 speaker box 'top hat' mount
2 200mm speaker grilles
2 8Ω 200mm coaxial speakers
1 40mm 12V fan
1 SPST mini rocker switch (S1)
2 9mm M3 tapped standoffs (for fan)
2 M3 × 10mm countersunk screws (for fan mounting standoffs to chassis)
2 M3 × 15mm machine screws (for fan mounting to standoffs)
1 solder lug
1 'P' cord clamp with M3 × 10mm screw, nut and washer
2 6.4mm crimp female spade connectors
1 200mm length of 10mm diameter heatshrink tubing (for covering charger and battery bracket)
1 red right angle banana plug
1 black right angle banana plug
1 2.5mm DC panel connector
1 2.5mm DC line plug
2 aluminium sheets 295 × 295mmm, 1mm gauge

1 350mm length of 12mm × 3mm aluminium
6 M3.5 tapped right angle (RA) bracket standoffs
16 M3 × 10mm machine screws (for mounting PCBs to chassis RA brackets to chassis – see note in construction article)
7 M3 × 15mm machine screws (3mm aluminium brackets to RA brackets, through 12mm standoffs on brackets 3mm aluminium to standoffs)
1 M3 × 20mm machine screw
10 M3 × 6mm countersunk screws (DC-DC Converter mounting, battery and charger brackets, RA brackets to chassis)
12 M3 nuts (RA brackets)
2 small cabinet handles (45mm long × 15mm high × 6mm wide or similar) (optional)
1 2-way 15A terminal strip (optional for extension speaker)
1 1m length of 7.5A figure-8 wire for speaker connections
3 1m lengths of 7.5A hookup wire (1 each red, black, green)
2 25mm length of 6mm heatshrink tubing (1 each red and black)
2 25mm length of 10mm heatshrink tubing (1 each red and black)
2 100mm cable ties

Box hardware

8 8g 12mm panhead wood screws (for speaker mounting)
24 6g 16mm countersunk wood screws (bronze) (for attaching corner protectors)
5 4g × 16mm panhead screws (for mounting chassis to cabinet)
1 500ml tin of contact adhesive
2 strips of putty adhesive (eg, Blu-Tack)
2 cushion bags of polyester wadding (eg, Innerbond)
1 3m length 18mm × 18mm DAR (dressed all round) pine
1 6m length 12mm × 12mm DAR pine
2 900mm × 600mm × 16mm sheets of MDF (or single 1800 × 600mm × 16mm sheet)

Resistor Colour Codes

	Total No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	2.2MΩ	red red green brown	red red black yellow brown
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	4	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❑	2	270kΩ	red violet yellow brown	red violet black orange brown
❑	6	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	2	30kΩ	orange black orange brown	orange black black red brown
❑	1	27kΩ	red violet orange brown	red violet black red brown
❑	4	22kΩ	red red orange brown	red red black red brown
❑	2	18kΩ	brown grey orange brown	brown grey black red brown
❑	3	15kΩ	brown green orange brown	brown green black red brown
❑	22	10kΩ	brown black orange brown	brown black black red brown
❑	4	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	12	1kΩ	brown black red brown	brown black black brown brown
❑	3	150Ω	brown green brown brown	brown green black black brown
❑	2	10Ω	brown black black brown	brown black black gold brown

Capacitor Codes

Value	µF Value	IEC Code	EIA Code
330nF	0.33µF	330n	334
100nF	0.1µF	100n	104
15nF	0.015µF	15n	153
10nF	0.01µF	10n	103
1.5nF	0.0015µF	1.5n	152
680pF	NA	680p	680
470pF	NA	470p	470
330pF	NA	330p	330
150pF	NA	150p	150
100pF	NA	100p	100
47pF	NA	47p	47
22pF	NA	22p	22
10pF	NA	10p	10

NEXT MONTH

We'll present Part 2 with all the construction details, including making and wiring the electronics.

TechnoTalk

Total hash

Mark Nelson

Did Neanderthals really create the hashtag? Why do people call this symbol 'hash', 'hatch', 'pound' or 'square'? And where does the 'octothorpe' fit in? As we approach the winter season of misrule, Mark Nelson indulges in a spot of mischievous (but genuine) history.

IN A RECENT ISSUE OF THE excellent *New Scientist* magazine, there was a fascinating article entitled 'Neanderthals drew first #hashtags'. Following the discovery of some scratches on the floor of a cave in Gibraltar, experts reached the conclusion that they were the work of a Neanderthal, made purposefully more than 39,000 years ago. The markings look like the grid for a game of noughts and crosses (without any noughts or crosses), prompting Catherine Brahic, the article's author, to muse whether this intentionally made artifact was an idle doodle, a game of Stone Age tic-tac-toe or the first evidence of Neanderthal art.

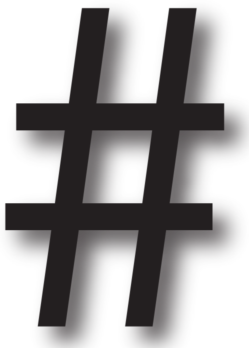
From the Stone Age to the present day

The age and authenticity of the scratch marks are not in dispute, as the cave in which they were found is littered with Neanderthal tools. Of course, Twitter didn't exist then (well it did, but only birds used it) so it's unclear why our friend Ug made this mark. According to Catherine Brahic, 'some say they are abstract symbols, bolstering the notion that Neanderthals were capable of subtle symbolic thought. Others remain to be convinced.' True, but the symbol is visually rather satisfying, which is no doubt why we still use it today on telephone keypads, computer keyboards and elsewhere.

Pound or hash?

Ask Americans for the name of this symbol and most of them will call it the 'pound sign' or 'number sign'. Over there, '#' is used where we would put 'No.', short for number. But it is also used for pounds weight. If you study pressure gauges on Victorian steam boilers (say, at the Kirkaldy Testing Museum in Southwark) you will often see the symbol used as shorthand for 'lb'. At rural street markets in Germany, where they still sell fruit by the pound (half a kilo), you will see '#' written on the price tags adorning apples and plums. Imagine the letters 'lb' written in sloping copperplate handwriting with no gap between the 'l' and the 'b', then you have a quick way of writing 'lb', of which '#' is merely a simplified version.

In Britain, computer people tend to call this 'hash', 'hatch' or 'gate'. 'Hash' is almost certainly a corruption of 'hatch', a word meaning a gate, grating or fence. All three of these are made from a combination of vertical and horizontal bars, so it's easy to see how the meaning was extended to a figurative representation as well. When the symbol was introduced onto telephone keypads, the comms industry realised that that the word 'hash' was not widely known outside computing circles, so here it was termed 'square'. On some keypads it is actually shown as a square, with no external projections.



Enter the octothorpe

The technical term for this symbol is 'octothorpe'. In my innocence, I knew that 'octo' was classical Greek for eight and assumed that 'thorpe' must be the Greek word for something sharp and spikey – wrong! A Usenet contribution written by Ralph Carlsen explains where the name really came from. Over to Ralph...

Around 1961, two Bell Labs guys in data communications engineering (Link Rice and Jack Soderberg) toured the USA talking to people who were thinking about telephone access to computers. They asked about possible applications, and what symbols should be used on two keys that would be used exclusively for data applications. The primary result was that the symbols should be something available on all (US) standard typewriter keyboards. The '*' and '#' were selected as a result of this study, and people did not expect to use those keys for voice services. Then, in the early 1960s, Bell Labs developed the first stored program-controlled switching system (it was a PBX). One of the first installations was at the Mayo Clinic. This PBX had lots of modern features (call forwarding, speed calling, directed call pickup), some of which were activated by using the '#' sign.

The originator revealed

A Bell Labs supervisor, Don MacPherson, went to the Mayo Clinic to train the doctors and staff on how to use the new features on this state-of-the-art switching system. During one of his lectures he felt the need to come up with a word to describe the '#' symbol. Don also liked to add humour to his work. His thought process, which took place while at the Mayo Clinic while giving lectures, was as follows:

- There are eight points on the symbol, so 'octo' should be part of the name
- We need a few more letters or another syllable to make a noun, so what should that be?
- Don MacPherson at this point in his life was active in a group that was trying to get Jim Thorpe's Olympic medals returned from Sweden. He figured that the phrase 'thorpe' would be unique, and people would not suspect he was making the word up if he called it an 'octothorpe'.

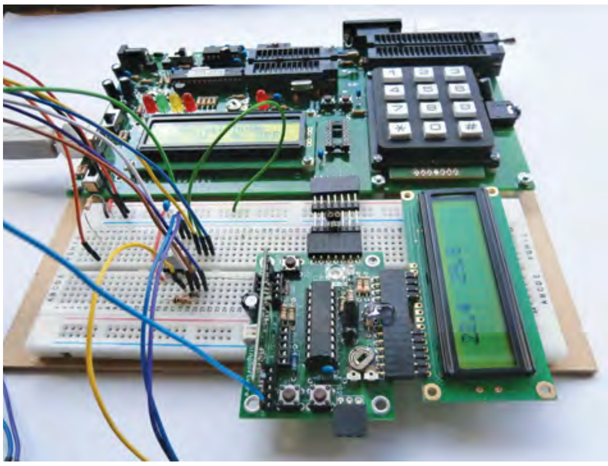
When Don returned to Bell Labs in Holmdel, he began using the term 'octothorpe' in memos and letters. The term was picked up by other Bell Labs people and used mostly for the fun of it. Some of the documents that used the term 'octothorpe' found their way to Bell Operating Companies and other public places. The rest is history.

...and back to hashtags

Despite this long and noble history, I suspect many people now know '#' simply in terms of hashtags. To quote the Oxford Dictionaries website, 'On social networking sites such as Twitter, it's attached to keywords or phrases so as to identify messages on a particular topic (eg, #volcano or #Iceland). These keywords or phrases are known as hashtags.' And according to Wikipedia, 'The first use of the term 'hash tag' was in a blog post by Stowe Boyd, 'Hash Tags = Twitter Groupings', on 26 August 2007.'

PIR and Radio

by Peter Brunning



The picture on the left shows the experimental circuit which I am currently using. The latest extension to our P931/P942 PIC training course is almost ready for release. Experimenting with 8, 14 and 20 pin PICs starts with a sequence of simple experiments to demonstrate the compatibility between 8, 14 and 20 pin PICs. We continue these experiments by adding a PIR movement detector to the circuit and adjust the software to trigger a siren sound. We add an LCD and send messages between PICs. We study radio data techniques and experiment with remote temperature measurement. The idea being to learn the techniques which we need to create a house security system. The final system uses several remote PIR detectors which when triggered operate a local low volume siren to deter the possible intruder and send warnings to the master circuit via the radio data link.

The system we create is relatively simple with one way radio data links and easy to understand software which is all built up gradually. But the system has provision to use two way data with each circuit having a radio transmitter and receiver. Two way data allows advanced security mechanisms to be used. So you are provided with all the background information and facilities to go as deeply into the subject as you wish. The software simplicity is centered around the latest version of our PIC assembler BSPWA which has a built in library with radio data subroutines.

The material for this extension consists of the book with 160 pages 240 × 170mm with wirobinding, experimental components for the plugboard experiments, several PCB supplied as kits, and a CD of the latest BSPWA. The first few experiments are suitable for complete beginners but ideally you should have worked through the first book of the P931 or P942 course.

The Brunning Software P931 PIC Training Course

This is almost a completely opposite system to the Raspberry Pi. We learn to use a relatively simple bare microcontroller. We make our connections directly to the input and output pins of the chip and we have full control of the internal facilities of the chip. We work at the grass roots level.

The first book starts by assuming that you know nothing about PICs but instead of wading into the theory we jump straight in with four easy experiments. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the alphanumeric liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music. Then there are two projects to work through. In the space of 24 experiments two project and 56 exercises we work through from absolute beginner to experienced engineer level using the latest 16F and 18F PICs.

The second book introduces the C programming language in very simple terms. The optional third book Experimenting with Serial Communications teaches Visual C# programming for the PC (not PIC) so that we can create PC programmes to control PIC circuits

P931 course..... £158 including UK carriage
Experimenting with Serial Coms..... £31.00

Web site:- www.brunningsoftware.co.uk

Mail order address:

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138 The Street, Little Clacton, Clacton-on-sea, Essex, CO16 9LS. Tel 01255 862308

Electronic Bellbird

By JOHN CLARKE

Photo by Sascha Wenninger – www.flickr.com/photos/sufw/9055617579

Looking for a great school project or a really unique Christmas decoration? This electronic Bellbird mimics the musical bell-like sounds of a real Bellbird (or Bell Miner) and includes a dynamic LED chaser display.

Bellbirds

And, softer than slumber, and sweeter than singing,
The notes of the bell-birds are running and ringing.
The silver-voiced bell-birds, the darlings of daytime!
They sing in September their songs of the May-time;
from 'Bellbirds',
by Henry Kendall

KNOWN FOR their characteristic tinkling bell sounds, the Bellbird (or more correctly the 'Bell Miner') lives amongst the eucalyptus tree canopies in south-eastern Australia. But while the bell-like sounds they make are very musical, their presence is not always completely appreciated. Intrigued? – check out the 'Bell Miners and Dieback In Native Trees' panel for more information on this.

By contrast, this *Electronic Bellbird*, which mimics the sound of a real bellbird, will always be appreciated. It's presented here as a stand-alone bell-shaped PCB with eye-catching LED lighting effects and a piezo transducer for the sound output. A 3V lithium cell powers the unit, which can be hung on a hook or nail on a wall, or even attached to a Christmas tree.

Like the real Bellbird, this electronic Bellbird only make sounds during the day or when there is sufficient ambient light. And like the real Bellbird, the sounds it produces are sets of bell sounds with randomised spacings and repetitions. This randomisation

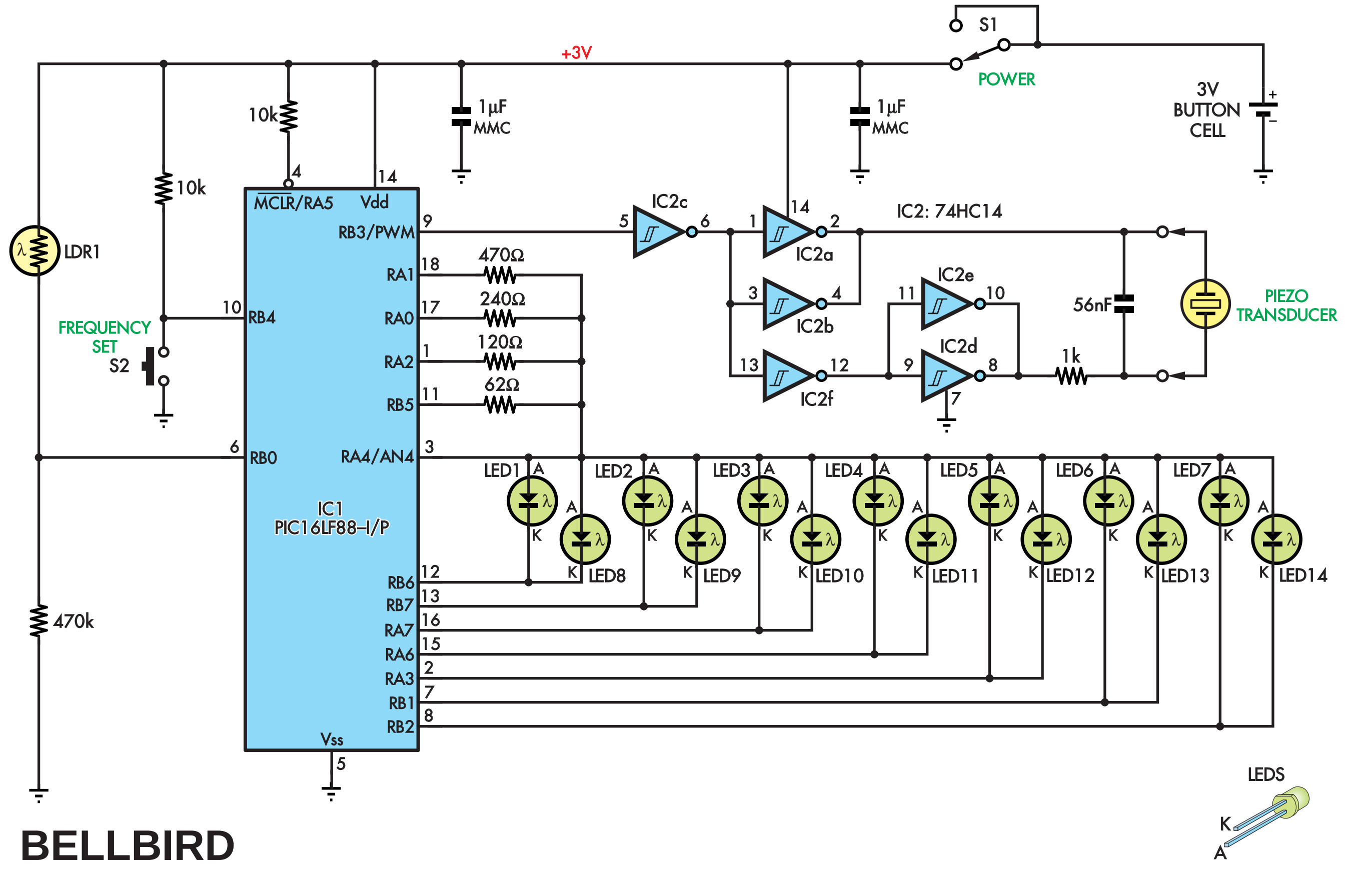


Fig.1: the circuit uses microcontroller IC1 to generate a PWM waveform at its pin 9 and this feeds Schmitt trigger inverters IC2a-IC2f which in turn provide complementary (push-pull) drive to a piezo transducer. IC1 also drives LEDs1-14 which are arranged in seven paralleled pairs to provide a chaser effect around the outside of the bell.

prevents the bell tones from sounding as though they are electronically generated. A power switch at the top of the PCB allows the unit to be switched off any time you want.

As well as producing realistic bell sounds, the unit drives 14 LEDs which are arranged around the periphery of the PCB. Whenever a bell sound is produced, these LEDs chase downwards on either side of the bell and then along the base to the centre. The six LEDs along the base then chase from the centre to either side and then back to the centre again, to simulate the final 'ringing' of the bell.

So, unlike a real Bellbird which is difficult to spot in the forest canopy, our unit is highly visible. It makes a great novelty project and is ideal as a Christmas decoration.

Circuit details

Refer now to Fig.1 for the circuit of the Bellbird. There's not much to it – just two ICs, 14 LEDs, an LDR and a few sundry bits. A piezo transducer reproduces the Bellbird sounds.

Inevitably, one of the ICs is a microcontroller (IC1). This is programmed to produce the Bellbird sounds via its pulse-width modulation (PWM) output at pin 9. Twelve other outputs of IC1 are used to drive the LEDs.

The PWM output is set to run at around 2.8kHz with some variation, and its duty cycle is varied to alter the volume. With a 50% duty cycle,

Features and specifications

Features

- Unit produces lifelike Bellbird sounds
- Bell-shaped PCB – LED chaser around outside; LEDs chase on bell sounds
- Constant LED brightness as cell voltage varies
- Bellbird sounds cease in darkness and low ambient light levels
- Low current drain plus power on/off switch

Specifications

Power supply: 3V lithium cell

Current drain: zero when switched off, <1µA in darkness (100nA measured), typically 1.3mA average in light.

Cell life: 180 days expected with one hour per day usage

Bellbird tone: adjustable over a ±12% range in 0.375% steps

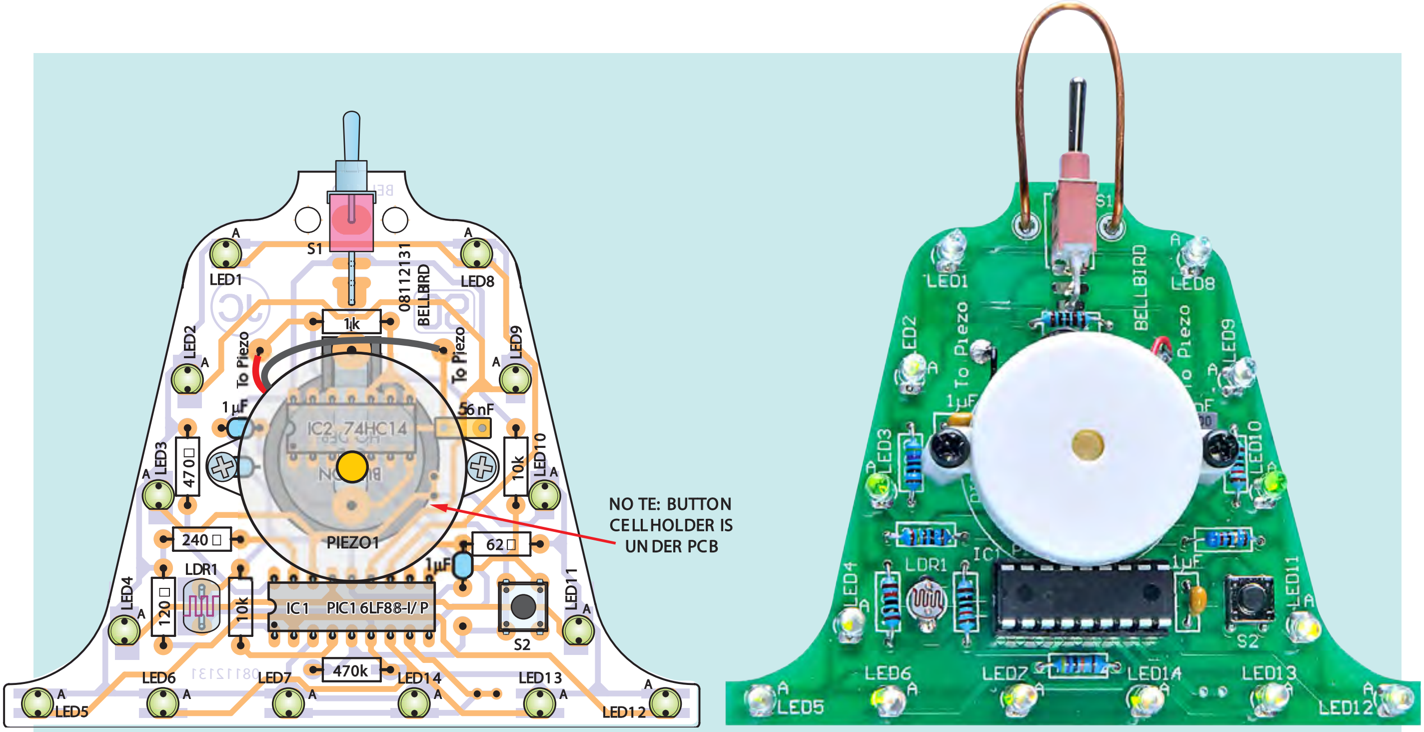


Fig.2: follow this parts layout diagram to assemble the parts onto the bell-shaped PCB. The piezo transducer is mounted on M3 × 9mm nylon spacers, while the button cell holder is mounted on the back of the PCB (see photo). Note that it's a good idea to mount the LEDs 5mm proud of the board so that they aren't obscured by other parts.

the volume is at its maximum, and as the duty cycle is reduced, the volume falls. The duty cycle ranges from 50% down to zero, with the minimum volume set at 0.2%.

The piezo transducer is driven via IC2, a CMOS hex Schmitt trigger. IC2c buffers and inverts the PWM output from IC1, while paralleled stages IC2a and IC2b re-invert the resulting signal to drive the top of the piezo transducer.

IC2f also inverts the signal from IC2c. Its pin 12 output in turn drives IC2d and IC2e so that their outputs are inverted compared to those from IC2a and IC2b. This allows the piezo transducer to be driven in complementary fashion with a nominal 6V peak-to-peak.

Basically, when IC2a and IC2b's outputs are at 3V, IC2d and IC2e's outputs are at 0V and vice versa. Because the two sets of outputs alternately swing to 3V, this gives a 6V peak-to-peak drive (actually >5V peak-to-peak) for the piezo transducer.

In effect, this doubles the output voltage drive compared to just using the PWM signal from IC1 as a single output, with the second terminal of the transducer connected to ground. That arrangement would provide a peak signal of less than 3V to the piezo transducer.

Note that IC2d and IC2e drive the lower piezo transducer connection via a filter consisting of a 1kΩ resistor and 56nF capacitor. This rolls off the response above 2.8kHz and thus removes the harmonics from the square-wave outputs of the Schmitt triggers. In effect, it ensures that a 'cleaner' sinewave signal is fed to the piezo transducer.

LED chaser

LEDs 1-14 are driven by IC1 as seven sets of paralleled pairs. In practice, they are arranged on the bell-shaped PCB to give symmetrical lighting either side of centre. For example, LED1 is positioned at the top left of the PCB, while its paralleled twin LED8 is positioned at top right.

As shown on Fig.1, the LED anodes are commoned and driven by IC1's

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
56nF	0.056µF	56n	563

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	1	1kΩ	brown black red brown	brown black black brown brown
❏	1	470Ω	yellow violet brown brown	yellow violet black black brown
❏	1	240Ω	red yellow brown brown	red yellow black black brown
❏	1	120Ω	brown red brown brown	brown red black black brown
❏	1	62Ω	blue red black brown	blue red black gold brown

Bell Miners and dieback in native trees

The Bell Miner (Manorina melanophrys), commonly known as the 'Bellbird', is found in the eucalyptus forests of south-east Australia. The birds feed mainly on dome-shaped protective coverings made by a particular psyllid bug from its own secretions. These bugs themselves feed on the eucalyptus from the leaves of eucalyptus or gum trees.

Colonies of Bell Miners allow large populations of the psyllid bug to exist in their territory by expelling other birds that also eat these bugs. They also maintain a sufficiently large territory so that they don't over-feed. This maintains the population of psyllid bugs and can lead to 'die back' in the eucalyptus forest.

RA1, RA0, RA2 and RB5 outputs via resistors. However, each of the LED pairs is driven independently via the cathodes, with LED1 and LED8 lighting when IC1's RB6 output goes low – and switching off when this output goes high. Similarly, LED2 and LED9 light when RB7 is low, LED3 and LED10 light when RA7 is low and so on.

The 470Ω, 240Ω, 120Ω and 62Ω resistors can be individually driven by IC1 or driven in various parallel combinations to power the LEDs. This allows the LED current to be maintained at a relatively constant value as the supply voltage progressively drops from 3V when the cell is new, down to 2V as the cell discharges.

The voltage across the lit LEDs always remains close to 1.8V, which leaves 1.2V across the resistors when the button cell is at 3V and just 0.2V across the resistors when the cell is down to 2V. By selecting the appropriate resistance, we can set the LED current to about 5mA regardless of cell voltage.

In operation, each resistor is effectively switched into circuit when its corresponding pin on microcontroller IC1 is set high. Alternatively, a pin can be set as an input to effectively disconnect its resistor and thus prevent it from contributing to the LED drive.

For example, when RA1 is high, the LEDs can be driven via this 470Ω resistor. Alternatively, when RA1 is set as an input, this resistor does not contribute to any LED current. Similarly, when RA0 is high, it drives the LEDs via the 240Ω resistor and so on.

If more than one output is set high, the corresponding resistors are driven in parallel. Taking them all high provides the lowest resistance possible (since they are effectively connected in parallel) and this is required when the cell voltage is down to 2V.

When the cell voltage is 3.0V, just the 240Ω resistor drives the LEDs. For any voltage between 2V and 3V, a suitable combination of resistors is selected so that the LED current is always close to 5mA.

Determining cell voltage

So how does IC1 measure the cell voltage so that the appropriate resistors can be selected? It's done by using the AN4 input to measure the voltage between the anodes of LEDs1 and 8 and the positive supply when these LEDs are driven via the 470Ω resistor at RA1.

In practice, the voltage across the LEDs remains close to 1.8V regardless of the variation in LED current, and so the measured voltage is proportional to the supply (ie, the cell voltage). As previously stated, at 3.0V the voltage measurement is 3.0 – 1.8V = 1.2V. With a 2V supply, the voltage measurement is 2.0 – 1.8V = 0.2V, and so on.

A look-up table in the software specifies which resistors should be selected for a given measured voltage.

LDR1 is used to monitor the ambient light, so that the LEDs only come on during daylight or in high ambient light conditions. This is done to conserve the cell and works as follows.

In darkness, the LDR's resistance is very high at several megohms and so pin 6 of IC1 is held low (1V or less) via its associated 470kΩ resistor. When IC1 detects this low voltage, it goes to sleep, stopping all operation and thus minimising the current drain from the cell. Typically, the current drain in this sleep state will be less than 1µA; in fact, our prototype's current was measured at just 100nA.

As soon as light is received by the LDR, its resistance falls to around 10kΩ and the voltage at pin 6 rises to almost the supply voltage. This causes the microcontroller to wake up and begin playing the Bellbird tones and driving the LEDs. Note that IC1 always checks the cell voltage each time it wakes up or when the circuit is powered up (via S1), so that it can correctly set the LED current.

Adjusting the tone

Switch S2 is used to adjust the Bellbird frequency (or tone). This is included because IC1 uses an internal oscillator that runs with an initial 2% tolerance.

Parts List

- 1 double-sided plated-through PCB, available from the *EPE PCB Service,* code 08112131, 91 × 73mm (bell shaped)
- 1 PCB-mount SPDT toggle switch (S1)
- 1 SPST vertical mount micro-switch with 6mm actuator (S2)
- 1 20mm button cell holder
- 1 CR2032 lithium cell
- 1 30mm diameter piezo transducer
- 1 LDR 10kΩ light resistance (LDR1)
- 2 M3 × 9mm tapped nylon spacers
- 4 M3 × 5mm screws
- 1 70mm length of 1.25mm enamelled copper wire

Semiconductors
- 1 PIC16LF88-I/P microcontroller programmed with 0811213A.hex (IC1)
- 1 74HC14 DIP14 hex Schmitt trigger (IC2)
- 1 DIL14 IC socket
- 1 DIL18 IC socket
- 14 3mm green high brightness LEDs (LED1-14)

Capacitors
- 2 1µF monolithic ceramic (MMC)
- 1 56nF or 47nF MKT polyester

Resistors (0.25W 1%)

1 470kΩ	1 240Ω
2 10kΩ	1 120Ω
1 1kΩ	1 62Ω
1 470Ω	

Can it be made louder?

Inevitably, some people will want to make this project louder and want to know what modifications are needed to achieve this. Hence, after the circuit had been fine-tuned to give the most realistic Bellbird sounds, we looked at whether the low-pass filter in series with the piezoelectric transducer could be further tweaked to make it louder.

To that end, we reduced the 1kΩ current-limiting resistor to 220Ω and increased the associated filter capacitor from 56nF to 220nF (the piezo transducer has a self-capacitance of 38nF).

The result was that it was slightly louder, but we judged that the sound was a little more 'clicky' (because of the stepped modulation) and had also lost some of the subtle echo effects, which make the Bellbird sound much more realistic.

Another way of making the sound louder would be to increase the supply voltage to 4.5V by substituting a 3 × AAA cell (alkaline) battery instead of the 3V button cell. Note that this will increase the peak signal voltage to about 7.5V.

Last, can the signal be fed to an external amplifier? The answer is 'yes' – but be aware that the signal has quite a wide dynamic range and the peak signal amplitude with a fresh 3V cell will be be in excess of 5V (or 7.5V peak with a 4.5V supply), so if the volume control is too advanced, the amplifier and perhaps the loudspeaker will be overloaded.

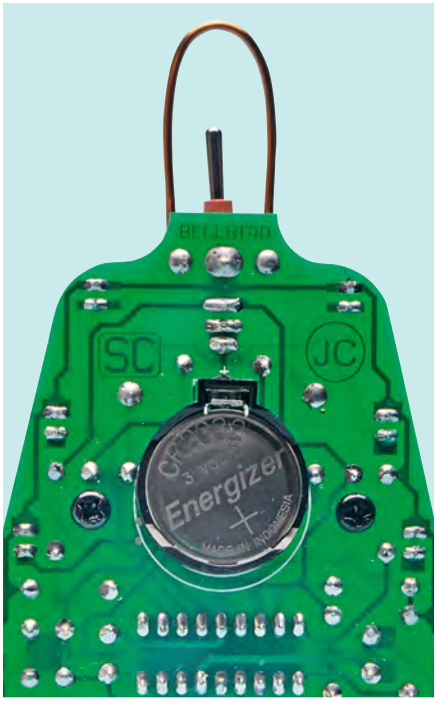
As a result, the oscillator frequency may need adjusting slightly to give the correct Bellbird sound.

When S2 is pressed, the resulting low on RB4 is detected by IC1 and the program then produces a series of bell tones, with each tone varying by a small amount (0.375%) for each step. The switch is simply released when the required tone is found. IC1 then stores this tone setting in its EEPROM so that the correct tone is used from then on, even if the power is switched off and on again.

If necessary, you can return to the initial default tone by pressing and holding down S2 as the Bellbird is powered up with S1. Alternatively, you can cycle through the available tones by holding S2 down until the centre frequency is reached. Since 64 separate tones are produced, the centre tone frequency occurs 32 tones after the transition from maximum to minimum, a tone step that's readily noticed.

S1 is the power on/off switch. The 3V supply is decoupled using a 1µF capacitor for IC1 and another 1µF capacitor for IC2. The $\overline{\text{MCLR}}$ pin of IC1 is a power-on reset input, and pulling it high via a 10kΩ resistor ensures that the microcontroller starts correctly (ie, at the beginning of its program) when power is applied.

Note that no reverse polarity protection is included to protect the ICs against incorrect supply polarity. That's because the cell holder itself does not make a connection to the cell if the latter is inserted incorrectly. Provided the cell holder is installed on the PCB properly, and IC1 and IC2 are both oriented correctly, then the circuit cannot be damaged by an incorrectly installed cell.



This view shows how the cell holder is mounted on the rear of the PCB. It must be installed before mounting the piezo transducer, so that you can solder its leads.

That said, we recommend that the supply polarity delivered by the cell in its holder is checked before installing IC1 and IC2 into their sockets. This is detailed later under 'Testing'.

Assembly

Building this project is easy and should take you no more than 45 minutes. There are no surface-mount parts (SMDs) and all parts are installed on a PCB, which is available from the *EPE PCB Service*, coded 08112131 and measuring 91 × 73mm overall. This is bell-shaped and will already be cut to shape if you ordered the PCB from the *EPE* Online Shop.

Fig.2 shows the parts layout diagram. As you can see, all parts mount on the top of the PCB except for the cell holder, which mounts on the back.

Begin the assembly by installing the resistors. Table 1 shows the colour codes, but we also recommend using a digital multimeter to measure each resistor, just to make sure that each is placed in its correct position. The resistors must be pushed all the way down onto the PCB, with the leads soldered and trimmed short on the back.

The IC sockets are next on the list – make sure they are oriented as shown on Fig.2 (ie, notched ends to the left). Don't install the ICs at this stage though; that step comes later, after some initial testing.

Follow with the capacitors and the two switches, again pushing these parts right down onto the PCB before soldering. Note that S2 will only mount with one orientation, as its pin spacings differ between adjacent sides.

The LDR can now be installed (it can go in either way around), after which you can install the LEDs. The latter must all be oriented with their longer anode leads (A) towards the top of the PCB. You can push the LEDs all the way down onto the PCB if you like, but we suggest mounting them about 5mm proud of the PCB so that they aren't obscured by adjacent parts.

The best way to go about this is to push each LED down onto a 5mm-high cardboard spacer (slid between its leads) before soldering it into position. To make this process easier, the leads can be soldered on the top of the PCB.

Next on the list are two M3 × 9mm stand-offs that are used to mount the piezo transducer. Secure these to the PCB using M3 × 6mm screws, but don't mount the piezo transducer at this stage. Once these are in place, install the cell holder on the rear of the PCB (ie, under IC2).

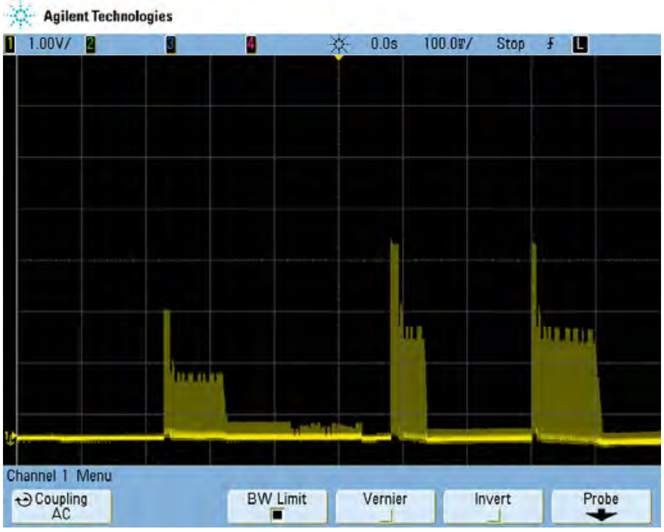


Fig.3: this scope grab shows part of a sequence of *Bellbird* 'calls'. Note that each one differs in amplitude, modulation and duration.

A hanging loop can now be made using a 70mm-length of 1.25mm-diameter enamelled copper wire. Cut it to length, then scrape the enamel from the ends using a sharp hobby knife before bending the wire into a loop. The wire ends can then be bent at right angles and soldered to the holes on either side of switch S1, at the top of the PCB.

Testing

Now for some initial tests before installing the ICs and the piezo transducer.

First, insert the cell into its holder, then switch the unit on using toggle switch S1. That done, check the voltage between pins 14 and 5 of IC1's socket. You should get a reading of +3V (ie, the cell voltage) on pin 14. Similarly, pin 14 of IC2 should also be at +3V with respect to pin 7 of this socket.

If this is correct, switch off and install the ICs. Make sure that both ICs are oriented correctly; ie, with the notch or pin 1 indentation at one end of each IC towards the notched end of its socket.

The piezo transducer can now be installed. It mounts onto the stand-offs after first drilling out its mounting holes to 3mm and is secured using M3 × 6mm machine screws.

Once it's in position, trim its leads to about 35mm long, strip 3mm of insulation from the wire ends and solder the leads to the pads on the PCB marked 'To Piezo'. It doesn't matter which way around you connect these leads; they can go to either PCB pad.

And that's it! You should now be greeted by musical *Bellbird* sounds when the unit is switched on and the LEDs should chase down the outside of the bell and along the bottom. If necessary, you can now change the *Bellbird* tone by pressing and holding S2 to set the *Bellbird* cycling through its output frequency steps. Release the switch when the required tone is heard.

If you want to return to the default frequency, switch the *Bellbird* off and wait a few seconds, then press and hold pushbutton switch S2 while you re-apply power. Finally, after a second or so, release S2 and the unit will again be at the default frequency.

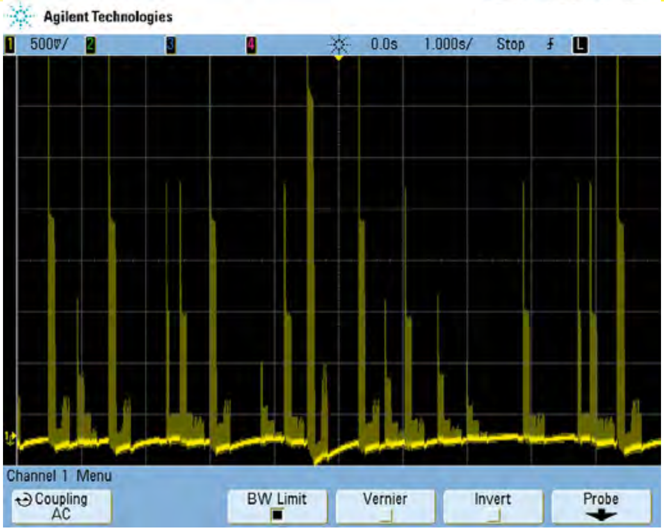


Fig.4: this shows a 10-second sequence of *Bellbird* calls. The scope has been over-driven to more clearly demonstrate the dynamic range of the signal which has a peak voltage of just over 5V. Again, note that there are a variety of 'calls', to simulate a group of Bellbirds calling in a forest.

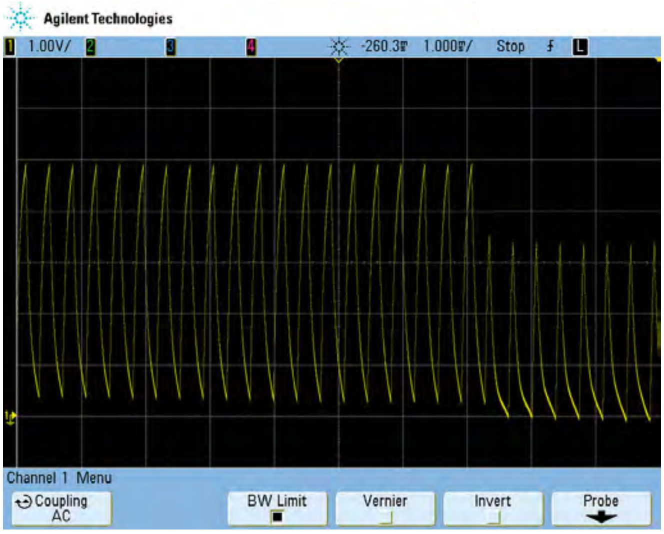


Fig.6: the *Bellbird* signal is a heavily filtered sawtooth waveform which is modulated in steps. The low-pass filtering has a –3dB point at about 2kHz.

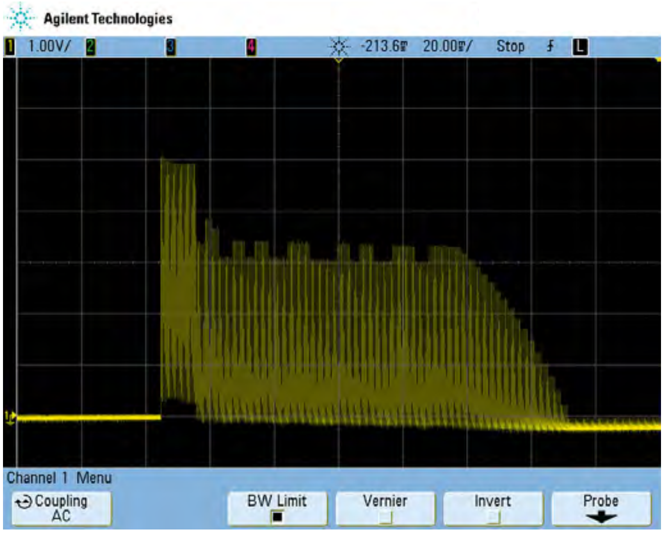
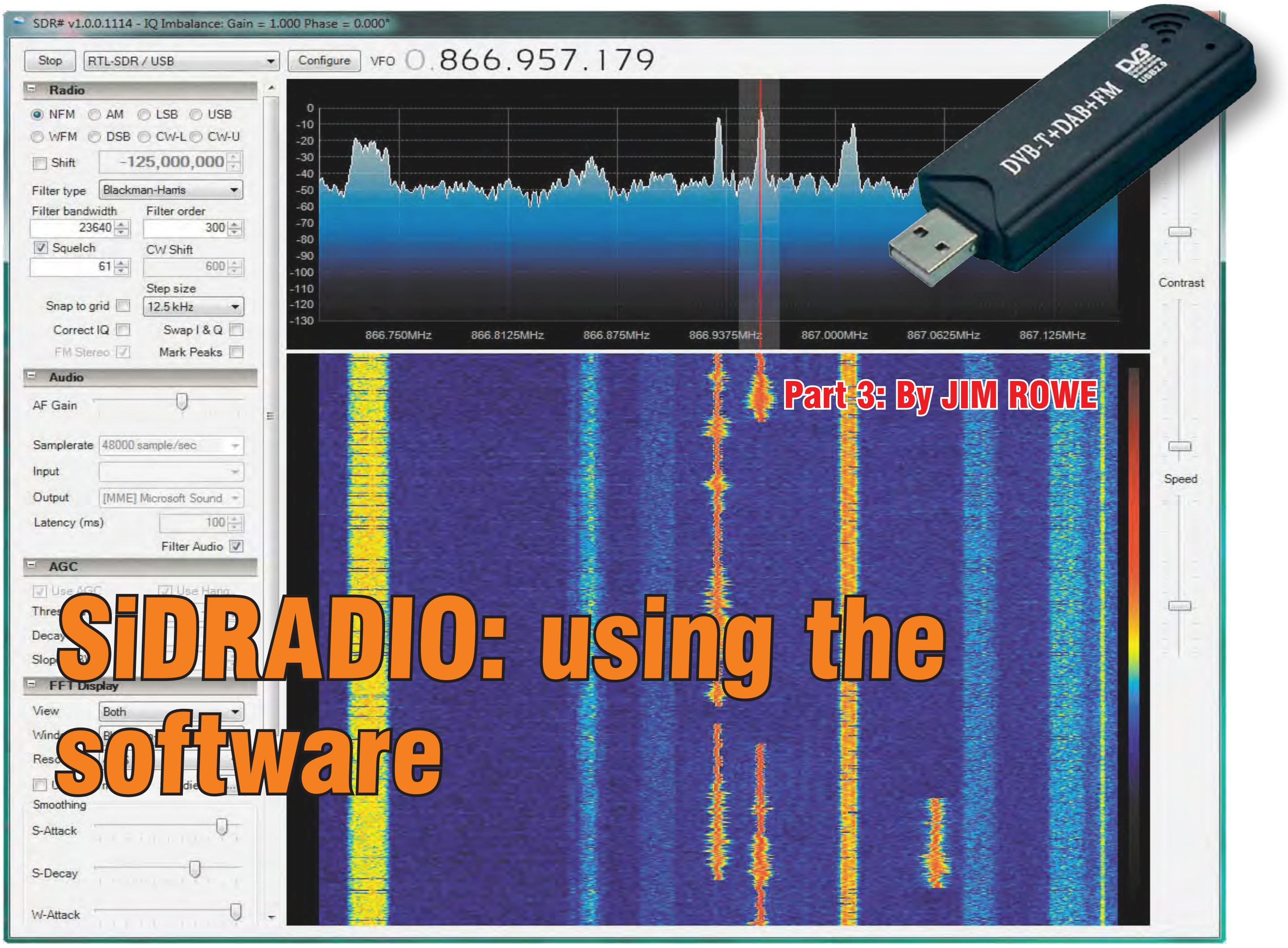


Fig.5: this scope grab shows just one *Bellbird* call, taken at a sweep speed of 20ms/div to show more detail of the complicated modulation, which is applied to each note.

SiDRADIO: using the software

Part 3: By JIM ROWE



Get an SDR covering a frequency range from around 50MHz (or lower) up to 2200MHz for just the price of a USB DVB-T dongle – peanuts!

OVER THE LAST COUPLE OF months, we have showed you how to build the hardware to use a cheap USB DVB-T dongle to turn your PC into a wideband VHF/UHF multi-mode SDR – a software-defined radio receiver.

Don't get us wrong – a USB DVB-T dongle/software-defined radio is not going to give you the same great performance as the excellent WiNRADIO Excalibur. However, it is going to give you a very wideband receiver with many of the facilities of a fully-fledged communications receiver. So let's look at the background.

Back in the late 1970s, firms in the USA and Germany began developing fully digital radio transmitters and receivers for use by the military and space industries. At first, these were classified, but gradually the results of this work started to percolate through into commercial 'software-defined' radio receivers and transmitters, in which many of the functions previously performed by dedicated hardware modules were performed by complex software or firmware.

The advantages were obvious: lower cost, lower weight and much greater functional flexibility.

It soon became clear that software-defined radio or 'SDR' was likely to become just another kind of PC application. This process received a dramatic boost in 2009 when Antti Palosaari, a Linux software developer in Finland, made an interesting discovery when he was working on Linux drivers and

Table 1: Common DVB-T Dongle Tuner Chips & Their Frequency Ranges

Tuner Chip	Frequency Range	DVB-T dongle model in which chip is found
Elonics E4000	52 – 2200MHz*	EzCAP EzTV668 DVB-T/FM/DAB, many current 'no name' devices
Rafael Micro R820T	24 – 1766MHz	? (not known – but may be in many future dongles)
Fitipower FC0013	22 – 1100MHz	EzCAP EzTV645 DVB-T/FM/DAB, Kaiser Baas KBA010008 TV Stick
Fitipower FC0012	22 – 948MHz	Many of the earlier DVB-T dongles

*With a gap from 1100MHz to 1250MHz (approx) NOTE: Elonics may have ceased manufacture

routines to allow DTV reception using one of the DVB-T dongles which had just started to appear. Delving into the firmware code inside the Realtek RTL2831U demodulator chip that was used in most of the early dongles, he found that it had an undocumented 'radio' mode, presumably intended to allow FM reception as well as DTV reception. In this mode, the chip would output a stream of 8-bit I/Q (in-phase/quadrature) digital samples via the USB port, at rates of up to 2MS/s (megasamples per second).

Antti Palosaari realised that this would allow other kinds of demodulation to be performed by software in the PC. This was confirmed when almost all later DVB-T dongles came with the higher-performance Realtek RTL2832U demodulator chip with the same in-built 'radio' mode as its predecessor.

So Palosaari got together with other software developers from Osmocom (the Open Source Mobile Communications group) and they soon developed suitable drivers and software for both Linux and Windows.

Now anyone can have a wideband VHF/UHF SDR, using a low cost DVB-T dongle and a PC or laptop. So let's take a look at what a typical SDR/USB dongle set-up can do.

Same hardware as before

Just as with DTV and DAB+ reception, the only hardware you'll need for using your PC as an SDR is the PC itself (with a free USB 2.0 port), a low-cost DVB-T dongle and a decent outdoor VHF/UHF antenna. Everything else is handled by software.

Which type of DVB-T dongle is best suited for use in an SDR? That depends on what range of frequencies you want to receive, because the main difference between most of the currently available dongles is their tuner chip. And the main difference between these tuner chips is their tuning range – see Table 1.

So, if you're mainly interested in scanning frequencies up to 1100MHz or so, almost any of the dongles will likely do the job. But if you want to tune much higher frequencies, you're going to need a dongle with either the Elonics E4000 or the Rafael R820T tuner chip inside – like the EzTV668 or many of the current 'no name' dongles.

Note that although the Elonics E4000 tuner chip covers the widest frequency range, it also has a gap between about 1100MHz and 1250MHz where it has no coverage. So if you are particularly interested in receiving signals in this region, you'll want to search the online market for a dongle with the Rafael R820T tuner chip inside. We're not aware of any just yet, but they're probably around on the web if you look hard enough.

Fig.1: an omnidirectional antenna like this Icom VHF/UHF discone is ideal for use with an SDR.

Remember too that dongles with the E4000 tuner chip in them may not be available for much longer, as Elonics has apparently gone out of business. So when the dongle makers use up their stocks of the E4000, many of them will have to swap over to the R820T anyway.

How about the antenna? Well, the tiny 'whip' antenna that comes with many DVB-T dongles is pretty useless even for DTV and DAB+ reception – and it's even more useless for SDR reception. So you're really going to need a decent outdoor VHF/UHF antenna.

For your initial SDR experiments, you'll probably get moderately encouraging results by using a standard TV antenna. However, as these are generally quite directional, they'll tend to be very insensitive to signals coming from directions other than directly in front. In practice, you'll get much better results from an omnidirectional VHF/UHF antenna like a 'ground plane' or (preferably) a 'discone'.

A discone is a wideband omnidirectional antenna with two main elements: a horizontal disc on the top and a conical shape below it (rather like an inverted ice-cream cone). Both the disc and cone elements may be made from either sheet metal or an array of stout wire 'spokes'. Sheet metal elements are more common in discones intended for use at frequencies above 1GHz, while 'spoke' elements are generally used for discones intended for use at lower frequencies.

By the way, the discone antenna was invented and patented by US engineer Armig Kandoian in the mid 1940s.

Some discones intended for use down into the lower VHF region have an additional vertical whip element at the top, to effectively convert the antenna into a half-wave vertical dipole at the lower frequencies. This is the case with the discone shown in Fig.1, which is a wideband VHF/UHF antenna made by Icom about 15 years ago. It originally sold for about £50 but

The SDR# application and its features

SDR# is an easy-to-use software application designed to turn almost any PC into a powerful SDR (software-defined radio), using either a DVB-T dongle (the hardware 'front end') or other devices. Here are some of its salient features:

(1) RF performance, frequency accuracy: the RF performance basically depends on the chips used in the DVB-T dongle used with SDR#. A typical dongle fitted with the Elonics E4000 tuner chip can tune from 52-1100MHz and 1250-2200MHz, with a sensitivity of approximately 1.5µV for 12dB of quieting at frequencies up to about 180MHz, rising to about 20µV for the same degree of quieting at 990MHz.

The SDR# software used with the dongle provides a frequency correction feature, whereby you can correct for any frequency error in the DVB-T dongle. In addition, there is a frequency shift feature, allowing you to display the correct frequencies even when you have an up-converter connected ahead of the dongle.

(2) Demodulation modes: AM (amplitude modulation), NFM (narrow frequency modulation), WFM (wide frequency modulation), LSB (lower sideband), USB (upper sideband), DSB (double sideband), CW-L (carrier wave with BFO on low side) and CW-U (carrier wave with BFO on high side).

In all these modes, the RF filter bandwidth can be adjusted over a wide range, while the filter type can be selected from a range of five (Hamming, Blackman, Blackman-Harris, Hann-Poisson or Youssef). The filter order can also be selected over a wide range. In both CW modes, the frequency separation of the software BFO can also be adjusted. There is adjustable squelch and also both linear and 'hang' AGC.

(3) FFT spectrum display and/or Waterfall spectrum/time display: the FFT spectrum display and Waterfall display can be selected either separately or together. The windowing function used can be selected from six choices: None, Hamming, Blackman, Blackman-Harris, Hamm-Poisson or Youssef, and the display resolution can be adjusted over a wide range by changing the block size from 512 to 4,194,304, in powers of two, with the higher resolutions requiring greater processing overhead.

Good results can be achieved with the default resolution of 4096, which was used for all of the screen grabs shown in this article.

Icom don't seem to sell them anymore.

However, Australian firm ZCG Scalar make what they call a 'Basestation Omnidirectional Broadband Discone'. Designated the B51H, this is available through their dealer network – see their website at **www.zcg.com.au**

If you search around on eBay, you'll find that suitable VHF/UHF discones are also available for online purchase. In particular, we found one from Mr CB Radio of Richmond, Victoria Australia. Another one called the 'Jetstream JTD1' was available from a couple of US suppliers (CQ Radio Supply and k1cra Radio Store) for between US$33 and US$56, with a further $50 or so for postage.

There's also information available on the web showing how to make your own discone, eg, see **helix.air.net.au** Another website at **www.ve3sqb.com** has software that works out the element dimensions for various antennas (including discone antennas).

Software is crucial

As with DTV and DAB+ reception, the software needed to configure a PC/dongle combination as an SDR consists of two main components: (1) a driver which allows the PC to communicate via the USB port with the Realtek RTL2832U (or similar) demodulator chip inside the dongle and (2) the application software to allow the PC to perform all the functions of an SDR in company with the dongle hardware.

The driver must be installed first. The most popular driver for a DVB-T dongle with an RTL2832U demodulator chip (when used as an SDR) is the 'RTLSDR' driver (nearly all dongles use the RTL2832U). There's even a website at **rtlsdr.org** which provides lots of information about it.

Zadig

The easiest way to install the RTL-SDR driver is to use an open-source driver installer program called 'Zadig'. Developed a couple of years ago by Pierre Batard, Zadig is currently available as version 2.0.1.160 in two forms, one for Windows XP and the other for Windows 7.

Both are about 5.2MB in size and they can be downloaded (as self-installing exe files) from **sourceforge.net/projects/libwdi/files/zadig**

It's important to get the right one for the version of Windows on the PC you'll be using for the SDR. Note that both files are compressed in a '7z' archive format, so you won't be able to extract the exe file from the download with WinZip. Instead, they can only be extracted using 7-Zip, a compression/extraction utility which offers a higher compression ratio. Fortunately, this too can be downloaded, either from **sourceforge.net** or directly from the 7-Zip developer's website at **www.7-zip.org**

7-Zip also comes in two forms – one for 32-bit x86 systems (ie, Windows XP) and the other for 64-bit x64 systems (eg, PCs running 64-bit versions of Windows 7).

If you don't already have 7-Zip, the first step is to download and install it. Then you can download the correct (and latest) version of Zadig, after which you can use 7-Zip to extract the *Zadig.exe* installer file. You then run this file to install Zadig itself.

With Windows 7, you have to run the installer file as the Administrator. This is very important, as otherwise it won't install Zadig correctly.

Next, plug your DVB-T dongle into the USB 2.0 port you intend to use for the SDR. Windows will then go through its usual rigmarole, looking for what it thinks is a suitable driver for the dongle. Don't worry if it does this though, because you'll be using Zadig to install the correct SDR driver shortly.

Now start up Zadig in the usual way. With Windows XP, you should immediately see the dialog shown in Fig.2. With Windows 7, you'll almost certainly get a User Account Control window first. Click 'Yes' to allow Windows 7 to run Zadig, to display the same start-up window.

Next, click on the Options menu and you should see a drop-down menu as shown in Fig.3. Click in the blank area just to the left of 'List All Devices' and the drop-down Options menu should disappear. However, there will now be some text displayed in the main

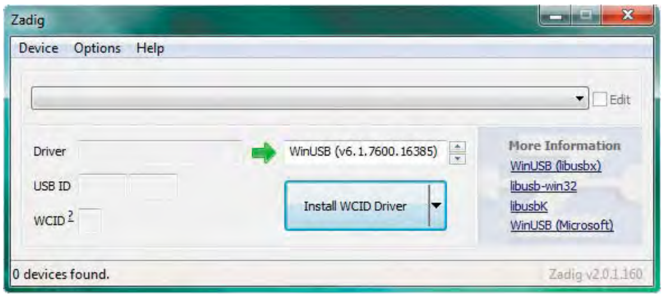


Fig.2: the Zadig startup window. This application is used to install the RTL-SDR driver to allow the PC to communicate with the Realtek RTL2832U demodulator.

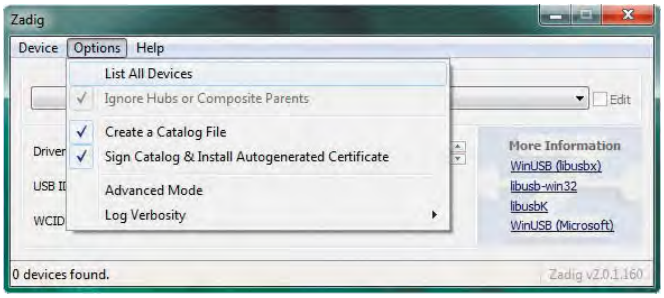


Fig.3: clicking the 'Options' menu brings up this dialog, after which you have to select the 'List All Devices' option from the drop-down list.

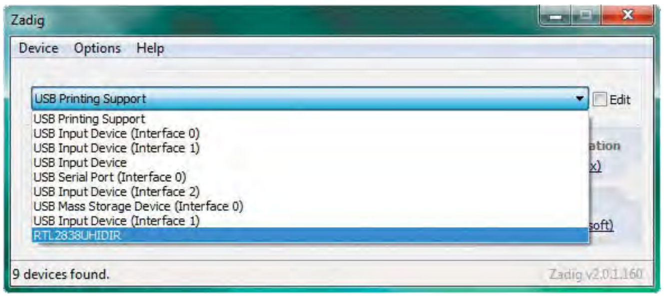


Fig.4: clicking the down arrow brings up the list of USB devices that Zadig has discovered. You then have to select the USB dongle entry from this list.

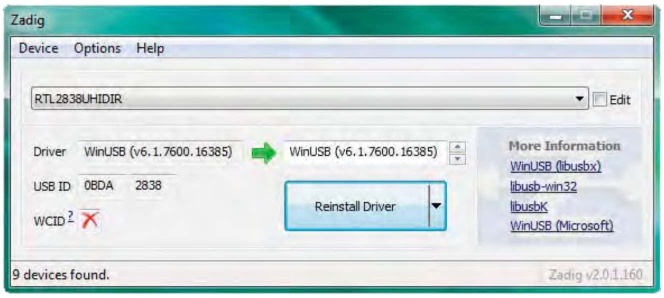


Fig.5: the RTL2838UHIDIR entry has been selected here (for an EzTV668 dongle). You then have to click the 'Reinstall Driver' button to install the correct driver.

drop-down menu bar, probably for one of your USB devices like a mouse, keyboard or printer.

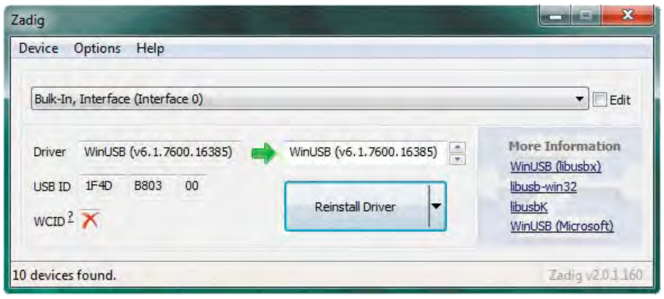
Click on the down arrow at the right-hand end of this bar. You should get a drop-down list of all of the USB devices that Zadig has been able to find connected to your PC – see Fig.4.

You now have to go through this list to find the DVB-T dongle that's plugged into one of the USB ports. The only catch here is that it can be listed under various different names, depending on the dongle.

Some dongles may appear as 'RTL2838UHIDIR', as shown at the bottom of the list in Fig.4, while others may be shown as 'Bulk-In, Interface (Interface 0)' as shown in Fig.6. Still others may appear as 'RTL2832U' or similar. The main things to look for are either that 'Bulk-In, Interface' label or one starting with 'RTL'.

When you spot the dongle in Zadig's list, click on its entry to highlight it. Zadig should now display the dongle's label in the main horizontal bar, as shown in Fig.5 and Fig.6. However, at this stage it either won't be showing anything in the Driver text box or it'll be showing whatever driver Windows installed (or tried to install) when you plugged the dongle into a USB port.

Fig.6: this screen grab is similar to Fig.5 but in this case, after Zadig has installed the correct RTL-SDR driver for Kaiser Baas KBA010008RT dongle.



Either way, you'll probably see text entries in the smaller boxes to the right of the 'USB ID' label, as shown in Figs.5 and 6.

Now turn your attention to the blue rectangular button at the lower centre of the Zadig window, which will probably be displaying the text 'Reinstall Driver'. If it isn't, click on the down arrow at its right-hand end and select Reinstall Driver from the resulting drop-down list. Once the correct text is displayed, click on this button to install the correct driver for SDR.

After 'whirring' away for a few seconds, Zadig should display a 'Successful Install' message and then you should see the correct driver name displayed in both the Driver text box and also in the box further to the right (just to the right of the green arrow). You can see the driver displayed in these boxes in Figs.5 and 6.

The driver should now be installed correctly and will be called up automatically whenever your dongle is plugged into the same USB port at a later time. So if you always plug the dongle into the same port when using it for SDR, you won't have to fire up Zadig to reinstall the driver again.

Conversely, if you plug the dongle into another USB port, you'll have to run Zadig again to reinstall the driver for that port. As a corollary to this, you will be able to use the same dongle for DVB-T and DAB+ reception simply by plugging it into a different USB port; ie, one for which Zadig hasn't installed a driver.

What's next?

Once Zadig has installed the SDR driver, exit the application in the usual manner. However, before you move on to download and install the SDR

application software, it's a good idea to go into Control Panel -> System and Security -> Device Manager to make sure that the driver has been installed correctly.

In Device Manager, scroll down to 'Universal Serial Bus Devices' (see Fig.8) and click on the arrow to the left. You should now see a device entry with the same name as that previously shown in Zadig (it's shown as 'RTL2838UHIDIR' in Fig.8). This will be your dongle and if you then right-click on this device name and select 'Properties', you should see another small window like that shown on the right in Fig.8.

Click on the Driver tab in this window and you should be presented with the details of the driver that Zadig installed. As shown in Fig.8, the Driver Provider should be shown as 'libusbx.org' and the Driver Version as '6.1.7600.16385' (or another number if it has been updated from the current version).

If that all checks out, then Zadig has correctly installed the SDR driver for your dongle and you're now ready to install the application software.

Our first choice: SDR#

If you search the web, you'll find a number of different SDR software applications that run under Windows or Linux and are compatible with RTLSDR dongles. The most popular of these seems to be an application called SDR# or 'SDRSharp', written by a programmer in Paris by the name of Youssef Touil in collaboration with various other people around the world.

SDR# is a particularly powerful and easy-to-use SDR application and it's available for free. It provides an excellent way to 'dip your toe' into SDR.

Fig.7: DVB-T tuner dongles can be purchased online quite cheaply. These three units all feature a 75-ohm Belling-Lee antenna socket but many other dongles come with a much smaller MCX connector.

Downloading and installing SDR# is a little tricky though, because it's not packaged as a 'single exe' or 'zipped exe' file. Due to licensing and packaging considerations, it has been split into two main zip files, which can be downloaded from the SDR# website – plus another zip file which must be downloaded from a different website.

Here's the downloading procedures, step by step:

STEP 1

Fire up your web browser and go to the SDR# homepage at **www.SDRSharp.com** Then click on the 'Downloads' heading to go to the downloads page. Here you'll find two main files. One will have a name like *SDR# Dev* or *sdr-nightly*, followed by a description in brackets like (Continuous Integration, Last Changes Rev: 1114). This is the main SDR# zip file, so download it first. That done, move down to the file named *SDR# RTLSDR Plugin*, which will have a similar description in brackets. This will be the latest version of the RTLSDR 'plugin' for SDR# and this is the second zip file to download.

STEP 2

Before leaving the SDR# website, scroll further down the downloads page until you get to a section titled 'Important note for RTL-SDR users'. This section provides links to various worthwhile items on SDR#, including a PDF file of the well-written *SDR# User Manual* by Henry Forte. You can download this PDF file by clicking on the link **www.atouk.com/wordpress/?p=153**

STEP 3

The next step is to download the third main software ingredient. This is 'rtlsdr.dll', the application extension which SDR# needs to communicate with the RTL-based dongle via the USB driver. This file can't easily be downloaded by itself, but it is in a collection of other files which can be downloaded from the Osmocom website at **http://sdr.osmocom.org/trac/wiki/rtl-sdr/**

To do this, scroll down to a section at the end called 'Attachments'. In the links beneath this heading, you'll find one with the rather odd name 'RelWithDebInfo.zip'. Click on this link and you'll end up on a page headed 'rtl-sdr: RelWithDebInfo.zip'. This file can now be retrieved by clicking on the 'downloading' link over on the right.

Installing the software

Having downloaded the three zip files, you can now proceed with the software installation for SDR#. Here's how it's done:

STEP 1

Unzip the *SDR# Dev.zip* (or sdr-nightly.zip) file. This will have about 14 files inside, all of which should be extracted to the folder into which you will be installing SDR#. For example, you could extract the files to *C:\Program Files\SDR#*, so it's a good idea to create this folder before you start.

Step 2

Unzip the second zip file, ie, with a name like *sdr-nightly-rtlsdr.zip*. This will probably have five files inside, plus a folder called 'config'. Extract everything to the same folder used to store the extracted files from the first zip file. That done, check the contents of the 'config' folder; there should only be one file with a name like *sdrsharp.exe.config*. Copy this file into the main SDR# folder, where it will over-write an existing file with the same name.

Step 3

Now for the third zip file you downloaded, ie, *RelWithDebInfo.zip*. Inside this file, you'll find two folders, one labelled '/x32' and the other '/x64'. If you look inside the /x32 folder, you'll see a file called *rtlsdr.dll*. This is the only file you need from this third zip file, so just extract this file and place it into the main SDR# folder with the others.

And that's it. Your copy of SDR# should now be fully installed and ready to run. All you need to do is go to the *C:\Program Files\SDR#* folder

(or wherever you have installed it), right click on the filename *SDRSharp.exe*, and select either 'Run' in Windows XP or 'Run as Administrator' in Windows 7.

SDR# in action

After a couple of seconds SDR# should spring into life and you'll see a fairly large window like that shown in Fig.9. This is the opening window for the current version of SDR#, V.1.0.0.114; later versions may look a little different.

At the top left of this window are two rectangular buttons, one labelled 'Play' and the other with the default label 'Other (Sound card)'. Clicking the down arrow to the right of this label will now bring up a drop-down device list similar to that shown in Fig.10. Click the 'RTL-SDR/USB' option then click the 'Configure' button.

SDR# will now open a very interesting supplementary window, as shown in Fig.11. This shows you the actual name of the dongle (in this case 'ezcap USB 2.0 DVB-T/DAB/FM dongle'), the tuner chip it contains (here an E4000), its maximum and default sample rate (2.048MS/s) and the default sampling mode (quadrature sampling). It also gives you options for setting the AGC functions available inside the dongle (RTL AGC and/or Tuner AGC) and for adjusting the RF gain.

In addition, there are options for setting a tuning offset (for when you're using an up-converter with the dongle) and for correcting any frequency error in the dongle's crystal-based local oscillator. We'll discuss these options later on.

For the present, just click on the 'Close' button at the bottom of this window, then take a close look at the main SDR# window. Down the left-hand side, you'll see the SDR# control panel. This is divided into a number of functional areas, each with its own heading – ie, Radio, Audio, AGC, FFT Display and finally two area headings at the bottom for SDR# plugins.

Within each area you'll find various control buttons allowing you to select a variety of functions and modes. For example, the eight small buttons at the top of the Radio section allow you to select the demodulation mode you want to use (NFM, AM, LSB, USB, WFM, DSB, CW-L or CW-U). Most of the other controls are fairly intuitive, like the AF Gain slider at the top of the Audio section. You simply drag this

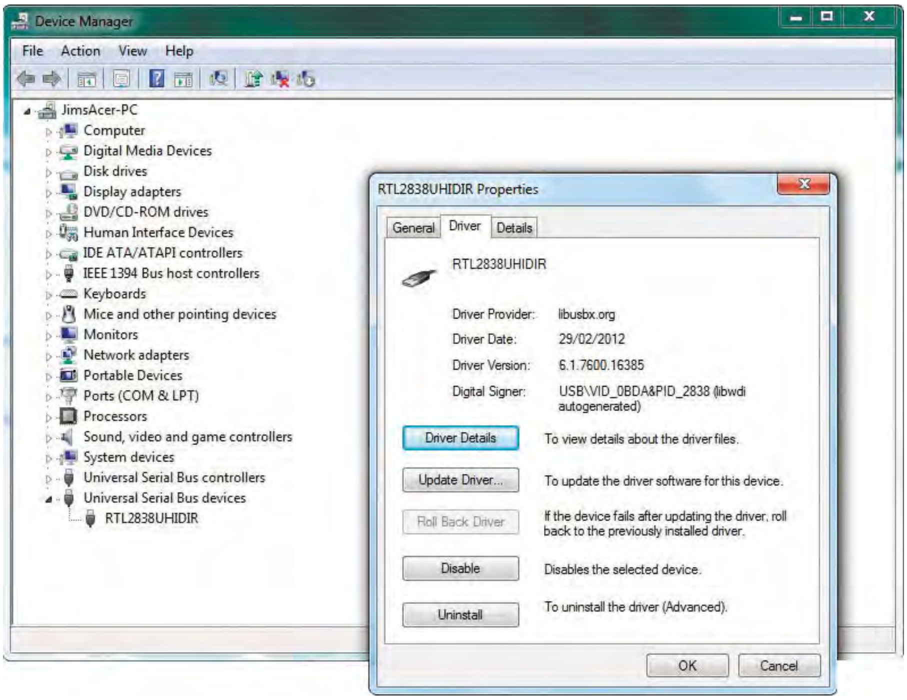


Fig.8: you can verify that Zadig has correctly installed the driver by checking the entry in the Windows Device Manager.

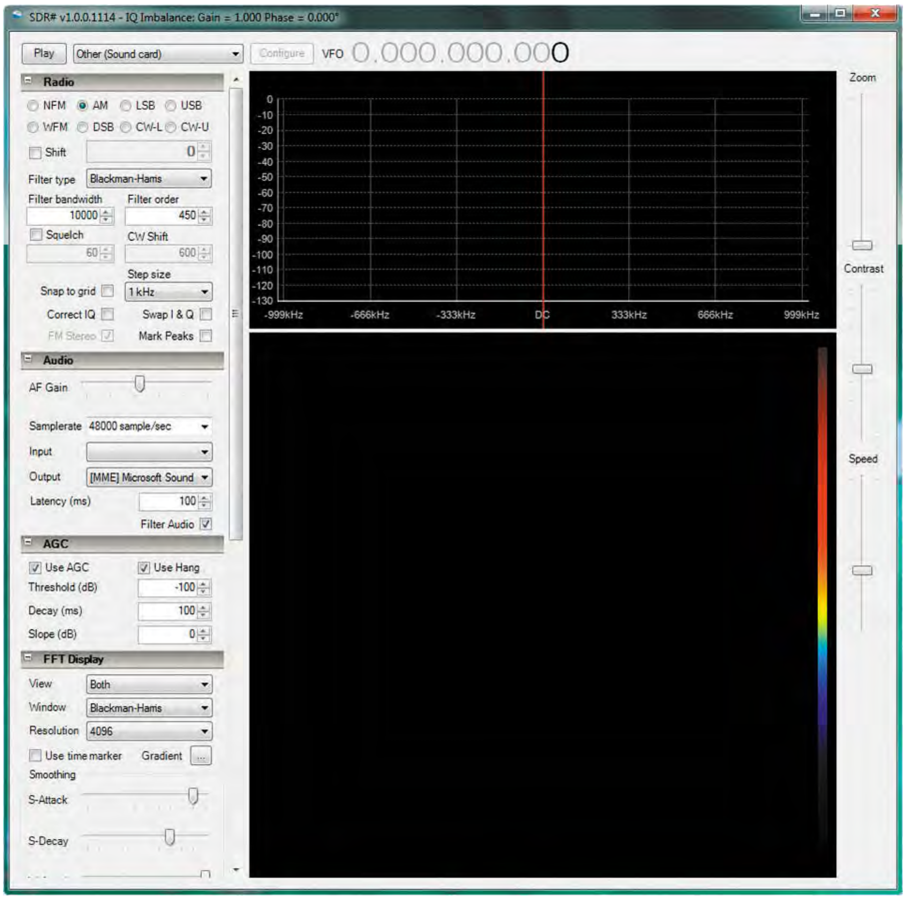


Fig.9: this is the opening window that appears when you start the SDR# program for the first time.

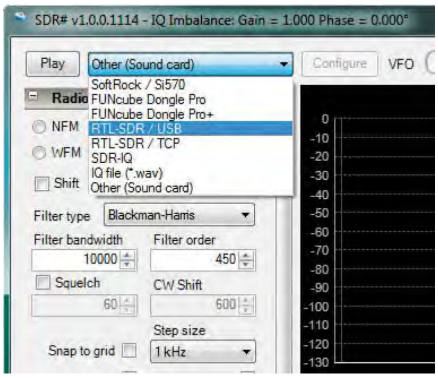


Fig.10: the 'Other (Sound card)' drop-down list. Choose the 'RTL-SDR/USB' option, then click 'Configure'.

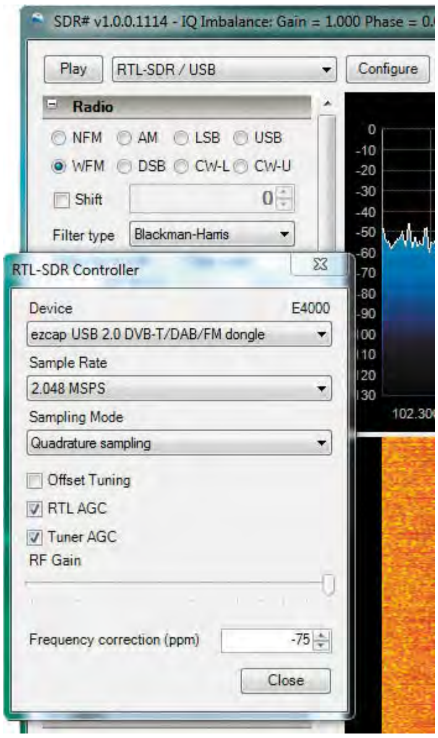


Fig.11: the RTL-SDR Controller dialog. It shows the name of the dongle, the tuner chip (here an E4000), its maximum and default sample rate (2.048MS/s) and the default sampling mode (quadrature sampling). There are also options for AGC and RF gain.

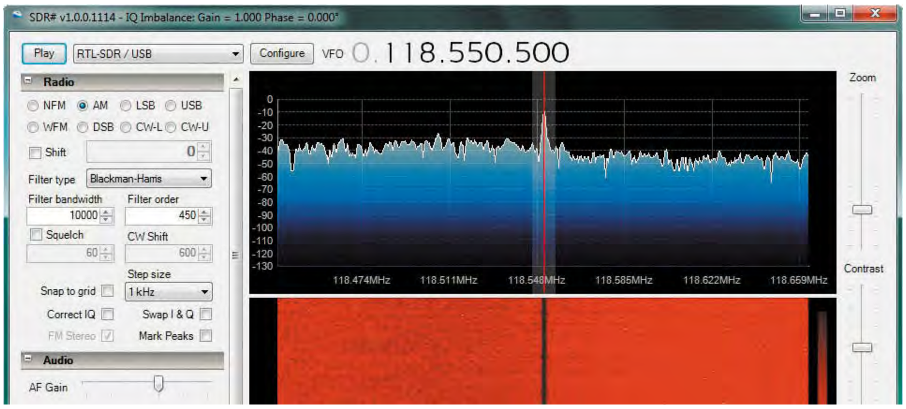


Fig.12: SDR# showing a typical spectrum display. In this case, the unit has been tuned to an AM signal on 118.550500MHz in the aeronautical band (the Sydney Airport Terminal Information signal).

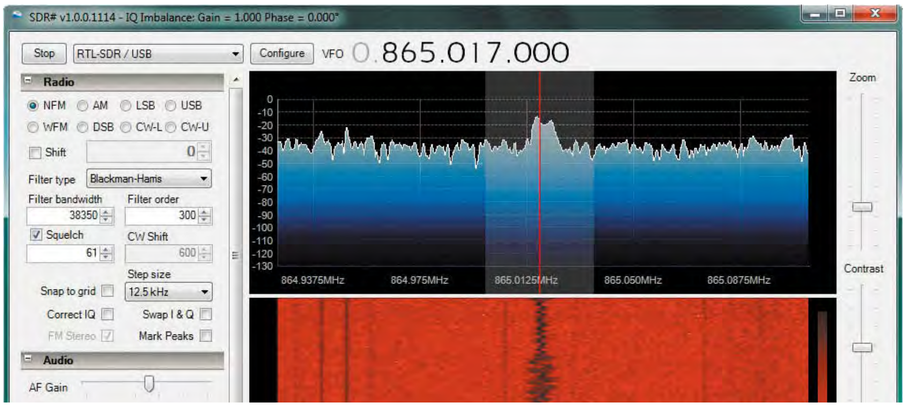


Fig.13: the result when SDR# was tuned to 865.017MHz in the UHF fixed/mobile communications band. The signal peak is a narrow-band FM (NFM) signal coming from a tourist guide on the Sydney Harbour Bridge.

slider one way or the other to decrease or increase the volume.

Tuning a frequency

In the centre at the top of the main SDR# window, you'll see the label 'VFO' followed by a string of 10 large numerals. At this stage, these will probably all be zeroes and with all but the rightmost digit 'greyed out'. This is SDR#'s main tuning frequency display and it's also where you can directly enter the frequency you want to receive.

Entering the frequency you want is easy: just move the mouse cursor over either the top half or the bottom half of any of the digits, which will cause a square of colour shading to appear behind that half of the digit (blue for the bottom half, or pink for the top half). Then if you left click on that coloured square, the digit will either increment or decrement to change the tuning frequency.

It reads directly in Hertz, so to tune your SDR to say 136.9125MHz you need to set the display to (0.)136.912.500.

Frequency/spectrum display

Just below the main frequency display is SDR#'s frequency/spectrum display window, which is probably its most impressive feature. This gives a continuous display of the spectrum in the vicinity of the tuning frequency you've set, with signal amplitude plotted vertically against frequency which is along the horizontal axis. This makes it particularly easy to spot the peaks or 'bumps' which correspond to any signals in that part of the spectrum.

If the frequency you want is actually away from the current tuning frequency, you can simply drag the tuning cursor (the vertical red line in the centre) over to the signal peak and drop it there.

By the way, if there are a lot of signals visible, all jumbled together in the spectrum display, you can zoom in to a smaller section of the spectrum display simply by dragging up the 'Zoom' slider on the right of this window. There are other handy features too, which we'll look at shortly.

For the present though, let's look briefly at one big feature of SDR# that we haven't yet mentioned: its 'waterfall plot' display window. This is just below the spectrum display window at lower right. Although this window is almost totally black in Fig.9, apart from a 'rainbow strip' at far right, when SDR# is receiving it displays a time plot of the visible signals in the spectrum display window.

This lets you see which ones are varying with modulation or appearing in short bursts (ie, with gaps in the signal). You can adjust the colour contrast within this window using the 'Contrast' slider at centre right and you can vary the time period represented by the waterfall plot using the 'Speed' slider below it.

Receiving a signal

OK, let's use it to receive a signal. There are really only three steps involved:

1) Enter the frequency of the signal you want to receive by clicking on the appropriate digits in the top display
2) Select the modulation mode (eg, AM, WFM, LSB etc) by clicking the corresponding radio button in the Radio section at top left
3) Click on the 'Play' button just above the Radio heading, at top left.

Within a fraction of a second, you should see a spectrum display like the one shown in Fig.12. In this case, the unit has been tuned to an AM signal on 118.550500MHz in the aeronautical band (it's actually the Sydney Airport Terminal Information signal). The display has been zoomed in a little and is showing the spectrum between about 118MHz and 118.66MHz, with the peak for the signal being received in the centre (bisected by the red tuning cursor line).

Looking closely at Fig.12, you'll also see a light grey band straddling the signal peak and the tuning cursor. This shows another of SDR#'s handy features – it can graphically display the software filter bandwidth currently in use.

If you change the filter bandwidth using the text box over in the Radio controls area, you'll see the grey band change width. But that's not all; you can also change the filter bandwidth by hovering the mouse over one side of the grey band until the cursor changes into a double-ended horizontal arrow. When it does, you can then click and drag the edge of the band one way or the other, to change the filter bandwidth.

What if you do find a signal peak but the audio output is badly garbled (even when you tune accurately to the centre of the peak)? This indicates that it's not using the type of modulation you've set SDR# to receive. That's fixed by clicking on the other mode buttons in the Radio area until the signal becomes clear. When that happens, you have the correct receiving mode.

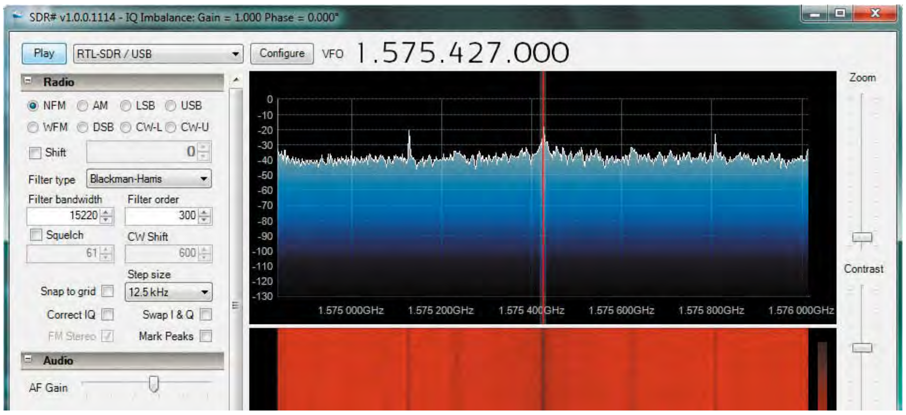


Fig.14: this screen grab shows the result when we set SDR# to receive the GPS 'L1' signal frequency at 1.575427GHz. There was indeed a small signal peak at that frequency, but we were unable to demodulate the signal because SDR# doesn't have an option to demodulate CDMA spread spectrum signals.

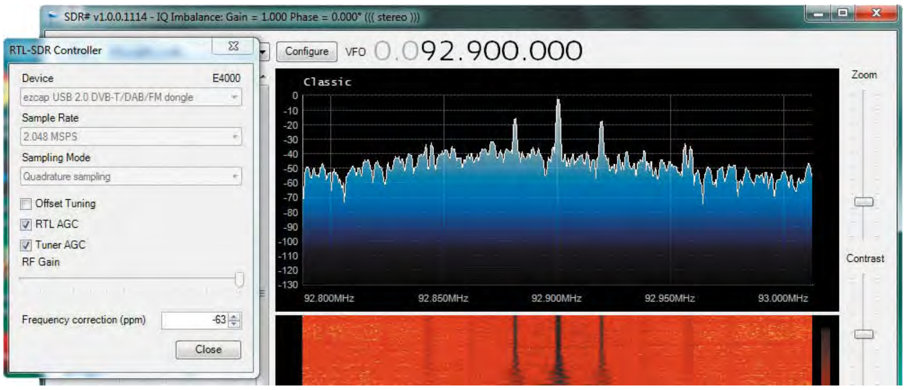


Fig.15: the frequency error in an EzTV668 dongle has been corrected here, in this case using the signal from ABC Classic FM in Sydney, on 92.900MHz. The frequency correction applied was –63ppm (parts per million).

As mentioned before, you can change the tuning frequency by clicking and dragging the red tuning cursor line in the spectrum display window. When you do this, you'll see the main frequency display at the top changing as you drag the cursor. In addition, the frequency 'dial markings' along the bottom of the spectrum display will also slide along.

If you want to shift the tuning frequency a long way from your current setting, it's much easier to click on the digits in the main frequency display at the top. If you like, you can think of this display as the SDR's 'band switching' control, while dragging the cursor in the spectrum display window is its 'fine tuning' control.

Two more screen grabs which should make the impressive capabilities of SDR# a little clearer are shown in Figs.13 and 14. Fig.13 shows the SDR# tuned to 865.017MHz in the UHF fixed/mobile communications band. The signal peak turned out to be a narrow-band FM (NFM) signal coming from a tourist guide up on the Sydney Harbour Bridge (he was explaining the history of the bridge and its surroundings)!

Fig.14 shows the result when we set the SDR# to receive the GPS 'L1' signal frequency at 1.575427GHz. There was indeed a small signal peak at that frequency, but its small size is not surprising since we were only using the wideband discone antenna shown in Fig.1. In any case, we were unable to demodulate this signal because SDR# doesn't have an option to demodulate CDMA spread-spectrum signals. Instead, all we could hear was a faint hum when the 'AM' demodulation mode was selected.

SDR# is also unable to demodulate DAB+ digital (COFDM) signals (perhaps this will be added in a future update). However, if you do want to listen to DAB+ radio, it's just a matter of plugging the dongle into a different USB port and firing up a DVB-T/DAB+ application.

Frequency error correction

At this stage, there's one aspect of the DVB-T dongle plus SDR# combination that we haven't considered: its tuning accuracy. Inside virtually all currently available DVB-T dongles is a 28.8MHz crystal oscillator. This is used as a clock generator and frequency reference by both the tuner and demodulator chips.

This means that the basic tuning accuracy of the dongle (and as a result our SDR) depends on the accuracy of this crystal oscillator. Not surprisingly, most low-cost dongles use a fairly low-cost crystal and its exact frequency can vary over quite a wide range.

To overcome this problem, Youssef Touil and his colleagues provided SDR# with an elegant way of compensating for this 'dongle tuning error'. This was done by building in a method to allow SDR# to automatically correct its frequency calculations by a known factor (which will be different for each dongle).

This may sound complicated but it's really quite easy. All you have to do is select a signal whose carrier frequency is accurately known and then set SDR# to tune to that frequency. Then when you click on the 'Play' button, you should see the carrier peak for this signal somewhere near the centre of the spectrum display.

The next step is to click on the 'Configure' button to call up the RTL-SDR Controller window and then turn your attention to the 'Frequency correction (ppm)' text box with its up/down arrows. It's then just a matter of clicking on one arrow or the other to move the signal peak so that it's centred on the correct tuning frequency.

If that still sounds complicated, take a look at Fig.15. This screen grab was taken after using the above technique to correct the frequency error in an EzTV668 dongle, in this case using the signal from ABC Classic FM in Sydney, on 92.900MHz.

As shown, the carrier signal peak has been moved right into the centre of the spectrum display, so that it straddles the 92.900 graticule line. And, as can be seen in the RTL-SDR Controller dialog box, this was achieved by getting SDR# to apply a frequency correction of –63ppm (parts per million).

This correction process only has to be done once for each dongle. Of the other three dongles we tested, one required a frequency correction of –115ppm and another a correction of +20ppm. The remaining 'no-name' dongle required no correction at all; it was spot on, probably by sheer good luck.

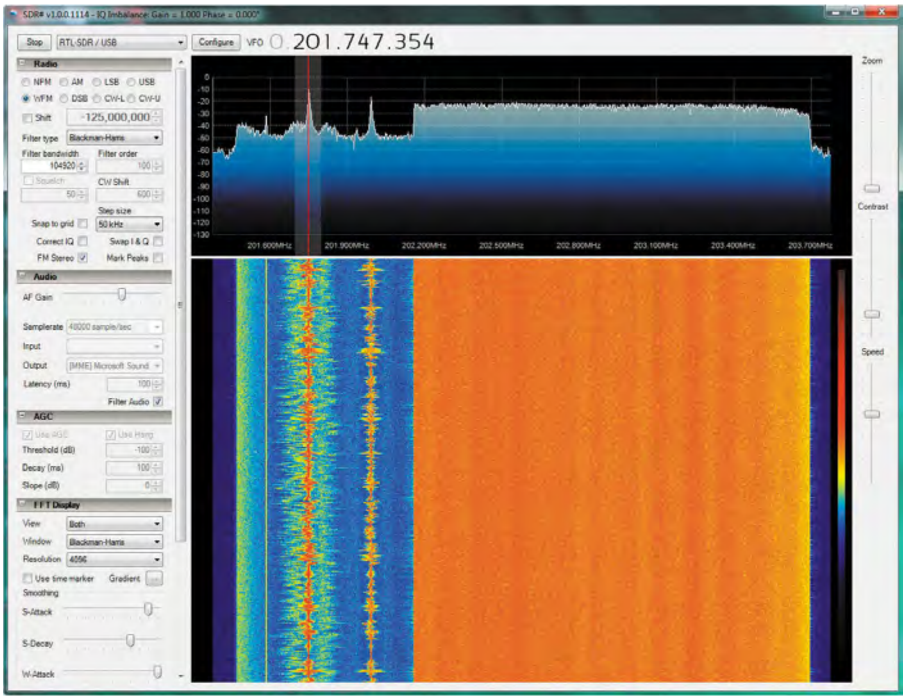


Fig.16: the spectrum and waterfall displays on SDR# for the Channel 9 sound carriers in Sydney. It shows the primary and secondary FM sound carriers for analogue Ch9, plus the DAB+ 'block' of multiplexed digital audio signals in Ch9A.

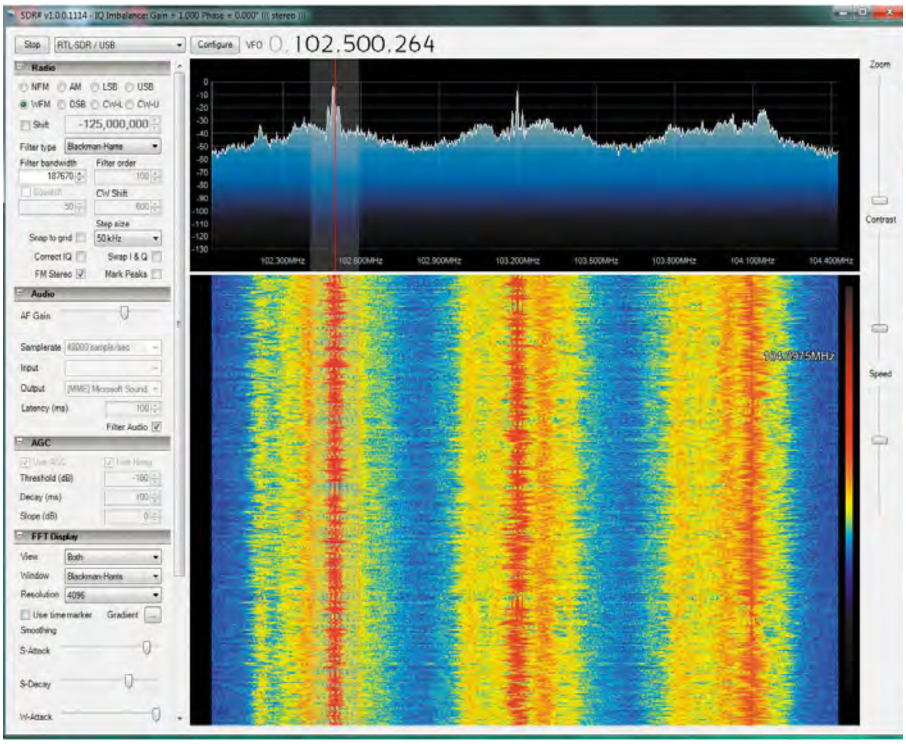


Fig.17: the spectrum and waterfall displays for three FM stations between about 102.5MHz and 104.1MHz.

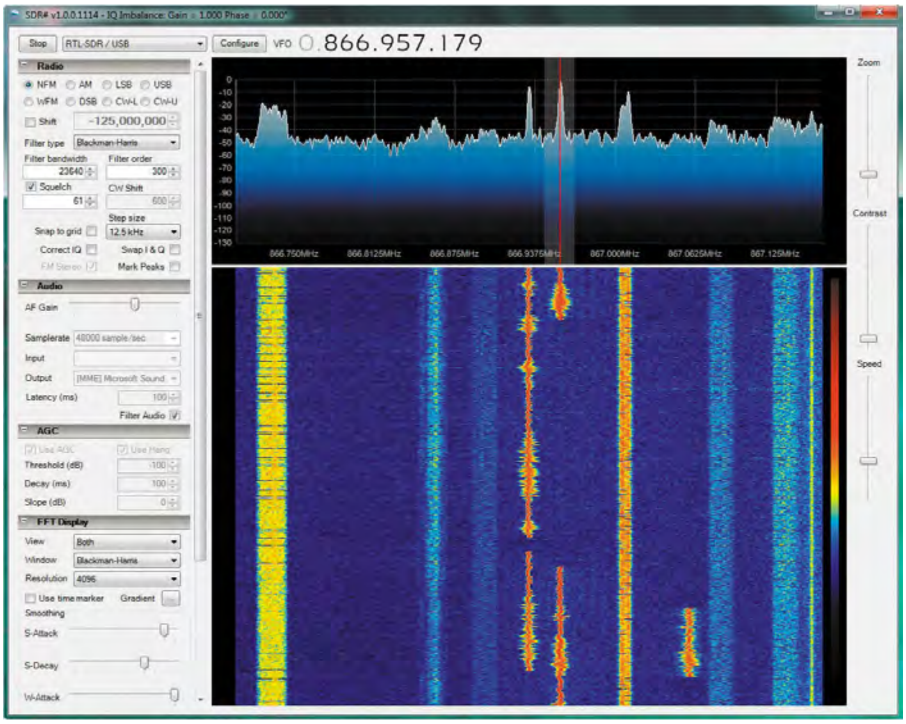


Fig.18: the waterfall display for several narrow-band FM (NFM) signals from Sydney airport (centre) plus various other digital signals.

Give it a go

So that's a quick run through the main features of SDR# and how easily it can be used to convert your PC into an SDR and wideband VHF/UHF spectrum scanner. It's a bit of a rigmarole to download and install the special RTL-SDR driver and then SDR# itself but once you've done that, the set-up is remarkably flexible and easy to use.

The only small 'glitch' we've encountered so far is that sometimes when exploring the VHF or UHF bands, there's a spurious signal peak in the centre of the spectrum display. This is probably due to signals radiated from the PC getting into the dongle. If you come across this, try enclosing the dongle in a metal shield and/or fitting the USB cable with a clip-on ferrite suppressor sleeve.

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50 Golden Years Of Practical Electronics

PART 2

by Alan Winstanley

In Part Two of our 50th Anniversary celebration of *Practical Electronics* magazine, we chart the progress of Britain's last remaining hobby electronics magazine from the 1970s to the present day.

New technologies

In the 1970s, semiconductor technology raced ahead: silicon had supplanted germanium, circuitry had gone 'digital', new light-emitting diodes offered colour, speed and power efficiency, CMOS technology was starting to emerge, and large-scale integrated chips were being released with applications in every sector of technology. A stylish Sinclair digital watch could now be built in kit form, as could a Sinclair 8-digit wrist calculator.

The chips byte back

Practical Electronics continued in the same vein of presenting projects of intermediate to advanced complexity, submitted by freelance contributors. One emerging area was really starting to make its presence felt: computing. Thanks to Intel, the era of the microprocessor was upon us, and *Practical Electronics* was keen to meet this challenge with tutorials, starting in 1975, followed in 1977 by the series *Microprocessors Explained*, written by RW Coles (who had previously designed the magazine's first digital IC project in December 1970).

The dawn of the home computing era became something of a double-edged sword. There were electronics hobbyists hungry to know more about programming and building computer kits, especially in the USA, but this new field could be a distraction from 'core electronics' project construction. Of course, those newly interested in computing also drifted into electronics as a complement to their hobby. In fact, *Practical Electronics* said that the Personal Computer Show held in Atlantic City in August '76 showed how the new hobby of home computing had taken both the electronics industry and retail trade completely by surprise.

The year 1977 would be one of upheaval, as IPC Magazines moved some operations away from London to Poole in Dorset, on the south-west coast of England. Editor Fred Bennett remained in London as editor of *Everyday Electronics*. Mike Kenward accepted the post of editor of *Practical Electronics* in Poole; he had returned to England after working for *Electronics Today International* in Canada. Having become divided, the two magazines went their own way and to some extent *PE* and *EE* became rivals. December 1977 was the last London-based edition and Mike's new team took over from the January 1978 issue of *Practical Electronics*.

Digital takes off

It has been said that *Practical Electronics* had resisted the temptation to carry many hobbyist-designed computer projects as developments were still racing ahead. Perhaps memories of the ill-fated *Digi-Cal* desktop calculator were still raw! A computer kit by MITS called the Altair 8800 claimed to be the first Intel 8080-based 8-bit computer kit to rival commercial units and *Practical Electronics* swiftly and characteristically rose to the challenge by publishing the *PE Champ* microprocessor development system. *Practical Electronics'* immensely successful *Compukit UK101*, a 6502-based design with 8K of RAM, followed in August 1979. It ran Microsoft BASIC and software could be uploaded on cassette tapes and some expansion possibilities tantalised the taste buds of hobbyists. A new branch of electronics technology – a computer hobby in its own right – had taken shape and the plethora of magazine titles on sale reflected that.

The July 1980 issue saw another milestone home computer product appear, one that would become the clarion call of home computing in Britain: the brilliant Sinclair ZX80, then the ZX81 and the Sinclair Spectrum, all light years ahead of the modest Sinclair amplifiers and radios that first appeared in November 1964's launch issue. Computer projects, including modems and Teletext followed, then in 1981 the *PE Car Computer*, a design with unsurpassed capabilities, and the *Telectric Digital* electricity cost meter, which also found its way onto BBC TV's *Tomorrow's World*. Home computers such as the BBC Model B and the Vic 20 were prime material for more computer-based projects in the years ahead.

The late 1970s had been a period of great turmoil in Britain, with industrial problems, recession and strikes doing great harm and the after-effects of this were felt in a decline in readership as well as advertising. Gone were the days of turning away advertisers from the magazine's overcrowded pages and both titles were caught up in

The April 1983, *Everyday Electronics* would be the last in this traditional style. Note the add-on project for the Sinclair ZX Spectrum home computer

***EE* was rebranded as *Everyday Electronics and Computer Projects* from May 1983, to appeal to the rapidly increasing number of home computer enthusiasts who, it was hoped, would explore microelectronics**

industrial supply problems, with deliveries becoming erratic at times. *Everyday Electronics* then entered the computing fray with a restyle, the April 1983 issue was the last before it morphed into *Everyday Electronics and Computer Projects*. The May '83 cover project sported a *Real-Time Clock* for Apple II and BBC Micro computers.

End of the IPC era

In 1985, IPC Magazines decided to dispose of a number of their titles including *PE* and *EE*. Following a brief period of stabilisation under its new owners, Intra Press, in 1987 *Practical Electronics* acquired a new editor: John Becker. Already known to many readers for his designs, including a post-Chernobyl *Geiger Counter* featured (again) on *Tomorrow's World*, John became editor literally overnight and quickly settled to produce *Practical Electronics* under the auspices of its new owner.

As I write, I have the November 1989 issue of *Practical Electronics* open at John's 25 Years Silver Celebration. The revised magazine itself would be different from before, and contained a lot more news, features and theory but less sleeves-up practical hobby electronics – much less. John was a true thoroughbred electronics hobbyist at heart, and had tremendous skills in design and authoring, as readers appreciated at the time. One did wonder whether it was a marriage made in heaven, and a decade later John confided to the writer that he did not always agree with the direction that its publisher seemed intent on going.

Both magazines were conscious of the competition as a multitude of titles jostled for the attention of subscribers. *Electronics Today International* hailed from Australia and the British version of *ETI* gave *Practical Electronics* a run for its money. Initially published by Modmags, *ETI* was perhaps a bit rebellious and it published projects and features in a style that was anything but stuffy or formal: if *PE* wore suits then *ETI* wore jeans! Another Modmags

***Electronics Today International* (*ETI*) rivalled *Practical Electronics* in the UK; its less formal approach found many friends. It merged into *EPE's* format in 1999**

Issue No.1 of *Hobby Electronics*, November 1978 was aimed squarely at the electronic hobbyist beginner's market – it became *Electronics Monthly* in late 1984

title called *Hobby Electronics* (November 1978 to October 1984 issues) took aim at *Everyday Electronics*. It eventually came under the same editorial auspices as *ETI* and changed to *Electronics Monthly* from late 1984. The 25th anniversary issue of *PE* also carried an item on a new niche magazine devoted to vintage radio called *Radio Bygones*, edited by *Practical Wireless's* Geoff Arnold, and eventually *RB* also became part of the *EPE* family.

By now, *Everyday Electronics* was revitalised and on the march, and bought up the interests of *Electronics Monthly*; so from the November 1985 issue the title changed to *EE&EM* and it enjoyed a buoyant run for the next seven years. A new publishing company owned by its editor Mike Kenward acquired the title *Everyday Electronics* in a seamless transition, so it was business as usual for readers. Indeed, in March 1986's editorial for *EE*, the first issue produced by the fledgling Wimborne Publishing Ltd, Mike reported a revitalised interest in constructional projects and a resurgence of courses in schools and colleges. He added that magazine readership had increased dramatically over the past few months, with sales of books and boards at an all-time high. One theory was that readers' interest in the new computing phenomenon had sparked an interest in interfacing and building peripherals.

The rise of the MCU

I will never know how events at *Practical Electronics* were panning out in the late 1980s, but I suspect that the writing was probably on the wall. Suffice to say that when I visited the *Everyday Electronics* office in late 1992, with a *Mini Lab* and *Micro Lab* under my arm to discuss *Teach-In '93* with editor Mike, there on the noticeboard was a mock-up of next month's magazine – sporting the brand new title of *Everyday with Practical Electronics* ('incorporating Electronics Monthly'). That's how I learned of the merger, as Mike, being

The first *Electronics Monthly* of November 1984, which in turn was snapped up by *Everyday Electronics* just a year later

Another rebranding exercise and *Everyday Electronics and Electronics Monthly* is launched! The Screaming Mask was just a co-incidence, we think...

progressive as always, had very skilfully acquired the rival title and brought its readers back under his umbrella. *EPE* was duly born from the November 1992 issue, which was celebrating the 21st Anniversary of the original *Everyday Electronics*. 'Never before had we encompassed such a wide spread of articles,' said Mike in his November Editorial.

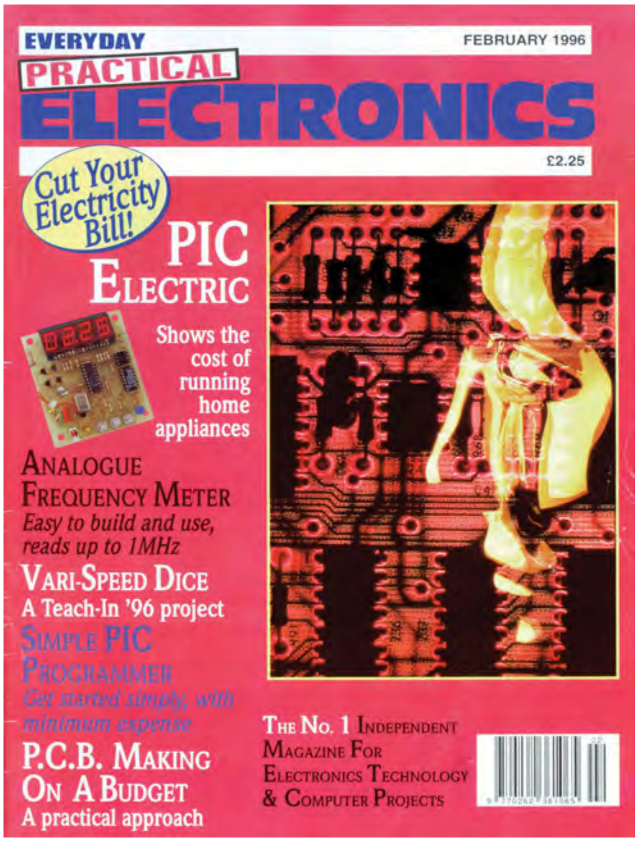
In the electronics hobby as a whole, techniques and technologies were changing faster than ever, and our hobby often trailed developments within industry itself. In a

The next iteration was *Everyday with Practical Electronics* (incorporating *Electronics Monthly*) from the November 1992 issue – *EPE* was born

burgeoning magazine market, the home computer sector was by now extremely buoyant and home users grappled with Microsoft Windows 3.1, floppy disks and modems. There was much more competition for a reader's pocket money, with video games and bulky computer magazines elbowing their way onto the scene.

Hobby electronics was perhaps in danger of suffering from another cyclic downturn, but one very clear trend was rapidly emerging as the hobby turned yet another corner in its evolutionary lifecycle: the microcontroller unit had arrived. The MCU would change the face of hobby electronics more than any other device in the past twenty years, and a powerful 'PIC' micro would eventually be cheaper than the 555 timer had been in its own era. March 1995's issue carried an article *Understanding PICs,* and PIC-powered projects soon followed thick and fast, many expertly written by John Becker who was now *EPE's* technical editor and who skilfully designed complex PIC projects apace. John realised the PIC's potential straight away, and starting from scratch he began utilising PICs in his projects with an impressive breadth of imagination. Other contributors, such as the much-missed Andy Flind, also produced some unforgettable designs, including the *EPE Mind PICkler* mind entrainment and relaxation system. The hobby was re-inventing itself all over again.

February 1996's issue included a small project that would have a profound influence on *EPE's* PIC-hungry readers:



PIC microcontrollers were fast becoming mainstream building blocks in our hobby. This February 1996 issue promised a *Simple PIC Programmer* by Derren Crome and a *PIC Electric Meter* by John Becker

a *Simple PIC 16C84 Programmer* by Derren Crome. Built on stripboard, this little project kickstarted the prospect of readers experimenting with these devices for themselves, and *EPE's* pages filled with ever-more appealing PIC designs that brought new levels of project functionality to hobbyists, along with a major reduction in their constructional complexity. Included in this issue was a *PIC Electric Meter* by John Becker. Hobbyists could now program a single PIC on a home computer rather than struggling with boards full of logic, and this transformed hobbyists' capabilities.

Microchip PICs

Early on, *EPE* decided to focus on the Microchip PIC family rather than spread itself too thinly across other devices and run the risk of being a digital 'Jack of all trades but master of none'. That is just how it happened, with the early interest shown in the PIC and the great support received from Microchip ensuring that *EPE* would soon dedicate itself to that family of devices. The fact that *EPE* also gave away its PIC microcontroller project source codes (many resulting from John Becker's unstinting efforts) as free downloads when an FTP site opened in 1996, further cemented the relationship with the PIC. (However, magazine articles could still be delivered to a fax machine using *EPE Fax on Demand*!)

There are far too many glorious and memorable PIC projects to list individually, but their legacy source codes are preserved at **www.epemag.net**. John Becker's *PIC Tutorial* series (March – May 1998) was proclaimed as the best ever PICmicro course, and was also released on CDROM. He went on to write *Teach-In 2000*, easing us into the new millennium with a PC-based tutorial series supported once again by generous levels of free interactive software that often accompanied his work. Sadly, John passed away in June 2009, but he left us his incredible legacy of material for future generations of hobbyists to enjoy.

The Internet arrives

The expansion of the Internet also influenced the magazine and its readership. In the mid-1990s, *EPE* had to explain to its readers what the Internet was about, starting with an article by the writer published in July 1996 (*The 'Net – what's in it for you?*). The *Net Work* column arrived a month later, giving readers updates on Internet trends and techniques.

A website URL slipped onto the October 1996 cover and a simple website went online, and for the first time our overseas readers, previously frustrated by the costs and delays of airmail, could feel more engaged thanks to the real-time website and email. Part of the original site is still online in our Resources section at **www.epemag.com**.

Silicon Chips

Humour occasionally crept into our pages. The April 1980 *Practical Electronics* issue announced some discoveries by a Welsh high-tech company (Llyis Electronics) that mined its own pure silicon from sand found on Prestatyn beach. Their powerful new ZMOS transistors featured a 'HEX-NUT' package and had micro-bore pipework that needed water cooling from a 30-gallon header tank. BBC Wales was duly taken in by this Silly Electronics April Fool, causing much mirth at the time. April 1996 *EPE* broke the story of *Chromo Floristics* – electronic colour control of plants using 'chromatic irradiation' with computerised LEDs. An impressive prototype with parallel port was shown along with a purposeful-looking BASIC program. This brilliant parody was again written by John Becker and the nation's media clamoured to learn more about the exciting discovery. The series *Ohm Sweet Ohm* offered some genteel humour in the 1990s and was written by Max Fidling – a pseudonym of the present writer, the surname picked at random from the phone book.

Download revolution

The Internet was clearly not going to go away and *EPE*, which had never rested on its laurels, became (we believe) the first magazine in the world that could also be downloaded from the web. As online payments were very hard to implement in the UK, our US team designed a custom system. In the late 1990s a new US operation run by Clive Maxfield (whom I had bumped into online, on Usenet), Dean Hudson and Alvin Brown created the website behind *EPE Online*. At last, anyone with Internet access anywhere in the world could download their own issue at the speed of light (nearly anyway). Clive ('call me Max') still blogs for *EPE* today. Then, right at the end of the decade, in addition to a new *EPE Online* graphic, March 1999's *EPE* sported another name change and a familiar logo, becoming *Everyday Practical Electronics with ETI.*

Testing times

Into the new millennium, and *EPE's* tried and tested formula was sorely challenged when several factors conspired in a perfect storm that created much uncertainty in the early 2000s. If there wasn't a general downturn in magazine circulations then a surge onto the world-wide web was widely predicted (incorrectly) to spell doom for printed magazines everywhere. The magazine presentation was looking tired and there were worries it would not appeal to the younger readers whom the hobby needed to attract and who were critical for its future. Key *EPE* staff also went into semi-retirement midway through the new decade, including founder member Dave Barrington who had been with *Practical Electronics* since Issue 1 in 1964, and John Becker sought a well-earned retirement as well.

Arguably, mainstream interest in traditional discrete electronics and its physics and principles was falling too, as witnessed by the decline

March 1999's *EPE* sported another name change and acquired the *ETI* logo, now so familiar to many readers

in quality contributions to the reader's own column of circuit ideas, *Ingenuity Unlimited*. In earlier years, an entire supplement of *IU* ideas could be printed due to the volume of contributions, but not now. More than anything, the old-school model for using freelance contributors finally ran out of steam. With pressure on editorial and technical resources rising fast, it became difficult to handle external material the traditional way, especially when it needed substantial re-working to make it publishable to the high standards that readers rightly expected.

A new publishing model

If *EPE* was to survive then drastic measures were needed. With the old way of doing things no longer viable, *EPE's* owner Mike Kenward took the brave and radical decision to use projects produced by Australia's *Silicon Chip* magazine. Their designs were thoroughly tried and tested in-house and the material was prepared to a very high, if differently styled, standard of presentation. *EPE* would therefore publish its constructional projects by joint arrangement with *Silicon Chip* and the January 2006 issue was in full colour for the first time, as Mike invested heavily in making the magazine more attractive. *EPE's* editorial features continued largely unchanged, with home-grown series such as *Teach-In*, *PIC n' Mix*, *Circuit Surgery*, *Net Work*, *New Technology Update* and *Actually Doing It* all appearing as before.

With most electronics magazines in the USA shutting down altogether, the deep financial recession of 2008 could have sounded the death knell for the hobby electronics magazine. Further streamlining took place at *EPE* when in 2012 our US site closed down, but an all-new website quickly sprang up in Britain: it had come home again! A new editor was also appointed, and *EPE* is now safely in the hands of Matt Pulzer, who has a very long association with the publishers and its readers. In 2012, a Pocketmags version for tablet users was released, followed by a new PDF version for online subscribers.

The world gets smaller, and after a dizzying voyage the final iteration – it is hoped – saw a redesign of *EPE* as high-quality projects from Australia's *Silicon* Chip were incorporated. The magazine was printed in full colour for the first time

Here comes the future

In the Anniversary edition of November 1989, *Practical Electronics'* Editor John Becker celebrated the past 25 years and mused about life 25 years hence – today in 2014. He correctly predicted driverless cars (Google), computer speech recognition systems and reckoned that the 50th Anniversary review could be spoken into a computer. We also have some low-energy products that he felt would be forced onto us by legislation – how very true. The EU recently banned the production of vacuum cleaners rated more than 1600W; lawnmowers, kettles, car air conditioning and hairdryers may be next in the firing line.

And what might *EPE* readers – and their families – see in the next 25 years? Products and devices in 2039 will be more mobile, networkable and always-on, wirelessly charged, wearable, disposable and recyclable than they are now. Today, much of our ADSL and FTTC depends on decades-old copper wires connected to our home, but tomorrow the 'cloud' will host most of our software services, made feasible by greater bandwidth and better fibre optic and wireless communications. There will undoubtedly be many ID and security-related challenges that will impinge on our personal freedoms, with biometric and scanning systems playing a major role in tracking citizens going about their everyday lives. Predictive text, speech and AI will result in computer systems second-guessing more of what we want to say or do, and then doing it for us. I am not sure that losing the need to use our brains will actually be a good thing!

Thanks to NASA's Space Launch System (SLS) a space shot to Mars is now a real possibility and there is no doubt that tomorrow's engineers will provide solutions that are smaller, faster, more accurate but use less power than before. The hobbyist will still be here, joining in the electronics revolution in one form or another. Whether there will be magazines like *EPE* still printed on 'dead trees' or there will be anything left that the home constructor can properly solder and coax into operation, only time will tell.

Image: NASA/MSFC

Celebrating this 50th Anniversary of *Practical Electronics* – with some *Everyday* experience included – has been a very humbling experience, with much awareness on the writer's part that we 'stand on the shoulders of giants', to quote an uncharacteristically humble Isaac Newton. Every issue since 1964 has represented much hard work and dedication by its contributors and staff, not to mention printers and distributors, all committed to enthusing the hobby electronics fraternity, embracing new developments head on and offering readers satisfying new projects to build. It has been thanks to Fred Bennett for having the foresight to drive *Practical Electronics* onwards to success and also *EPE's* publisher, Mike Kenward, his family-owned company and team, that we can still produce a hobby electronics magazine in Britain. Most of all, it is also thanks to you, our readers, for staying with us for the past 50 years and enjoying the ride along the way. Fingers crossed, here's to the Diamond Jubilee in 2024 and beyond!

A very rare photo of the 'boss' Fred Bennett and young assistant editor Mike Kenward presenting a prize to *EE* reader David Riley (right) in the December 1973 issue of *Everyday Electronics*

Editor John Becker in at the deep end: John toasts readers after reaching the milestone of 25 years of *Practical Electronics*, in a special November 1989 issue

ANNIVERSARY 50 YEARS ANNIVERSARY

NET WORK

by Alan Winstanley

Virus vigilance

IN last month's *Net Work* some current anti-virus options for computer users were highlighted. A number of software suppliers provide anti-virus products for PC, Mac, Android and iOS, and popular free choices for PC users include AVG, Avast and Avira Free Anti Virus. Advertising or 'nag screens', encouraging users to buy an upgrade, often support free products, but they do a fair job of providing real-time coverage against viruses or web-based Trojans. Protection is never 100% though, and anti-virus programs typically bundle extra tools or try to sell a full 'Internet Security Suite' version with anti-spam, anti-malware or web-surfing protection built in. Other perks, such as a free Dropbox file exchange package may also be included.

Paid-for software may have a few extra features and is sold on an annual subscription basis, with anti-virus updates ceasing once the service period expires. Discounts may be available to cover several years or multiple computers. At the time of writing, for the home PC user, AVG (**www.avg.com**) charges £29.99 for one year's basic anti-virus protection for a single computer. Rival Avast Pro (**www.avast.com**) has the same annual price but offers discounts for multiple PCs or several years (eg, £59.99 for one PC/three years, or five PCs/one year). A slightly cheaper paid-for product is the highly rated Avira Anti Virus Pro (**www.avira.com**), a single PC costing £25.99 for a year or £51.99 for three years, A licence for five PCs costs £54.99 for one year, while AVG charges no less than £149.94 for the same type of package. AVG also offers a Business Edition with discounts for longer periods.

Before switching to a different anti-virus program the previous one should be comprehensively uninstalled, which might need a Windows Registry clean-up tool such as the excellent Advanced Uninstaller Pro (**www.advanceduninstaller.com**). As I mentioned last month, I experienced severe problems removing a paid-for version of AVG on an older XP machine, and at one stage I had to reinstall AVG once again – luckily, I still had the serial number. After several lock-ups, the relevant uninstaller tool from AVG was used as a last resort (see: **www.avg.com/gb-en/utilities**) which forced a succession of reboots and DOS pop-ups and then Advanced Uninstaller did an excellent job of cleaning up any remnants from the system. Last, I installed Avast, which went in without a hitch. Avast's graphical display is good and the software is easy enough to navigate around. I also like the Windows desktop widget and the (English-accented) voice prompts, and an Avast screensaver can be configured to scan files in slow time.

Avast Free Edition has a useful updater that checks for current versions of software

Sneaky software

Like similar products, be prepared to see nag screens periodically that are easily dismissed. A number of tools are bundled in with Avast that might be of interest to readers. One of them is 'Software Updater', which warns when certain installed software is out of date. This is a useful one-click way of patching vulnerable key programs such as Adobe Reader or Adobe AIR.

Another benefit (opinions differ) of Avast is a price comparison plug-in called 'SafePrice' that was silently installed and occasionally pops up when visiting e-commerce sites. It flags up lower prices that may be available in so-called participating trusted websites, typically on eBay. Data is transferred anonymously, it is claimed, and the service is provided by the **ciuvo.com** network.

SafePrice is installed by Avast and can search for lower prices. Not all users welcome this hidden add-on though

SafePrice has worked well once or twice, popping up out of nowhere to flag up some useful savings on clothing for example, but nevertheless there are the nagging worries that Avast installed SafePrice without permission – or maybe the opt-in just flew under the radar – and that users' shopping habits are potentially being silently tracked by third parties. The standard response at such times is that personal data is removed, but there remains the worry that 'they' know everything about your shopping habits except your name. Whether or not affiliate fees are gathered by users' shopping click-throughs is another moot point.

There are also some minor bugs regarding SafePrice's Firefox compatibility, as the erroneous information published by Avast (**http://blog.avast.com/2014/03/27/how-does-avast-safeprice-work**) describing how to disable SafePrice was completely wrong. Until this bug is patched, open a Firefox window and go to **chrome://wrc/content/options.html** to see the Avast Online Security settings, where SafePrice can be disabled. In Internet Explorer, click a tiny green icon next to the address bar (blink and you miss it) to access Avast options and SafePrice can be disabled there. If you don't have Avast but want to try the add-on anyway, online shoppers can install it direct from the Ciuvo website and see whether it saves you any money.

The green Avast options icon is almost hidden in Internet Explorer

A benign feature like Software Updater is handy, but installing what is effectively adware like SafePrice without being up-front about it is something of an own goal, as trust is inevitably brought into question. Other Avast users have also complained that the file sharing service Dropbox was silently installed without their permission. Avast is a long-established and generally reputable product, but it sometimes feels like a work in progress. Provided that users are aware of any sideloaded services like SafePrice or Dropbox, Avast's anti-virus protection is probably worth its (free) price though, otherwise consider free editions of Avira or AVG, or download a 30-day free trial of Kaspersky as an alternative. I hope to report on Avira in a future column.

Suffering from shellshock

The widely-reported Heartbleed bug (*Net Work*, July 2014) related to a serious flaw in OpenSSL which could permit encrypted user data to be extracted from a vulnerable server. Heartbleed also allowed attackers to impersonate users or eavesdrop on communications. The vulnerability did not necessarily only affect web hosts or ISPs – an increasing number of home users also have network-attached storage (NAS) systems that go beyond the role of a simple hard disk. For example, the popular Synology NAS range is a stand-alone Linux-based server in its own right, and its operating system is updated periodically with enhancements; earlier this year an urgent Synology upgrade was rushed out to patch the Heartbleed bug. Synology is no stranger to malware threats, and the dreaded SynoLocker 'ransomware' exploit that emerged earlier this year showed how important it is to keep a system up to date to eliminate vulnerabilities: unpatched Synology units could have user data encrypted with no hope of recovery without paying a ransom. Synology users should set up automatic OS updates, and in my case the NAS sends an email automatically when a new upgrade is available. Unfortunately, acting as an unpaid systems administrator is fast becoming a new role for owners of domestic networks, with vigilance being a key watchword.

Heartbleed ranked as one of the world's most serious and immediate online threats – until now. Shellshock (CVE-2014-6271) relates to a hitherto undiscovered fault with the widely-used Gnu Bourne-Again Shell (BASH) that is more than twenty years old. Linux-based servers that run Apache web server, Apple computers running OSX and embedded products based on Linux are all potentially vulnerable to the Shellshock bug.

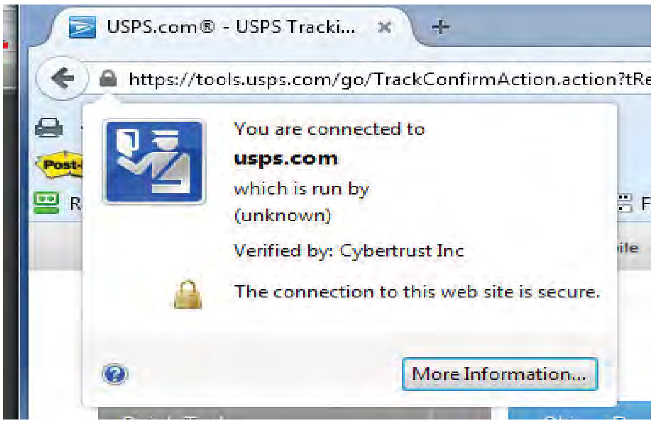
The fault allows a wide range of exploits to be performed, including password database theft, installing back door vulnerabilities and dropping malware onto target systems. It has the potential for enabling 'click fraud' to be committed, where advertising revenue is stolen by falsely generating clicks on advertising links. Unlike Heartbleed, which drip-feeds sensitive data, Shellshock allows powerful commands to be executed remotely by attackers. It's because BASH is taken for granted on Unix, Linux and Apple systems that the potential for Shellshock wreaking havoc is so huge. Newspaper headlines scream of an 'Internet Meltdown' and the UK National Computer Emergency Response Team (CERT) has assigned Shellshock the highest possible threat level.

Several attempts have already been made to patch the problem, but further patches are being released that will finally finish the job, or so it is hoped. Expect to hear more about the problems caused by Shellshock in the coming months. More details and practical advice to counter the threat are at: **https://www.cert.gov.uk/resources/alerts/update-bash-vulnerability-aka-shellshock**

Securely searching

A whole industry that was designed to influence search engines by giving websites a higher ranking sprang up in the late 1990s when 'search engine optimisation' (SEO) was born. Google refines its search results over time and it makes more than 200 calculations 'on the fly' when deciding how highly a website should be rated in its listings. The search giant is going much further in refining its results though: for example, it now analyses the core website design and construction, searching for examples of 'responsive design' – sites that work well on tablets or mobile phones as well as on desktop monitors. Google now classifies 'responsively designed' websites as more desirable and is likely to give them greater prominence than 'classically styled' static websites in its search results.

Next, Google will have a preference for sites hosted under secure website addresses, SEO industry insiders say. Readers might have started to notice how more website addresses commence with **https:** showing that a secure sockets layer (SSL) is in use. SSL was previously reserved for capturing secure data or e-commerce transactions, but is now also used for secure mail transmission, FTP and increasingly website hosting, where greater security is provided. A secure certificate supposedly vouches for the identity of the secure server owner. Using SSL, data that flows between the web browser and the secure server is encrypted to help prevent eavesdropping. This security measure is not 100% bulletproof, though. For example, in some extremely isolated cases, secure certificates have been wrongly issued by a certifying authority, and it is feasible that third parties could impersonate a certificate holder and intercept transmissions using a 'man-in-the-middle' attack, but this is exceptionally rare. One has to balance the risks: a bank's systems can be secure until a fraudulent IT engineer plants a 3G keylogger on a staff computer – over £1 million was stolen from Barclays Bank this way.



Checking SSL details in Firefox

Web surfers know that the golden padlock icon shows that the secure certificate is in order, and SSL problems may be highlighted using a red background in Internet Explorer's address bar, perhaps with a broken padlock symbol appearing. In Firefox, you can click the grey padlock icon to view secure certificate details. Error messages do pop up in browsers if a secure certificate does not seem to 'belong' to the web server, particularly when accessing a shared server that hosts multiple websites: maybe the secure certificate legitimately belongs to the ISP rather than an individual website's domain. When considering website security, visitors should take an informed decision based on reputation and 'look and feel' before deciding whether or not to proceed further: in the case of online shopping, credit card suppliers do not provide fraud protection if credit card numbers are entered into a clearly insecure site. SSL errors can often be dismissed, but it pays to be vigilant nonetheless. Web surfers should expect to see greater use of SSL in website URLs in the future, if only to help improve a site's Google rankings.

You can email the author at: **alan@epemag.demon.co.uk**

INTERFACE

By Robert Penfold

Raspberry Pi B+ A/D

RECENT *Interface* articles have been based on the very popular Raspberry Pi computer, which was originally available in two versions. Earlier this year the existing A and B models were augmented by a new model, which is called the B+. Supply for the new Raspberry Pi was initially outstripped by demand, but availability is now much better. Thankfully, the B+ is essentially the same as the model B, and it runs the same operating systems and application software. There are some changes on the hardware side of things, which are mainly improvements, and it is largely compatible with Model A and B hardware.

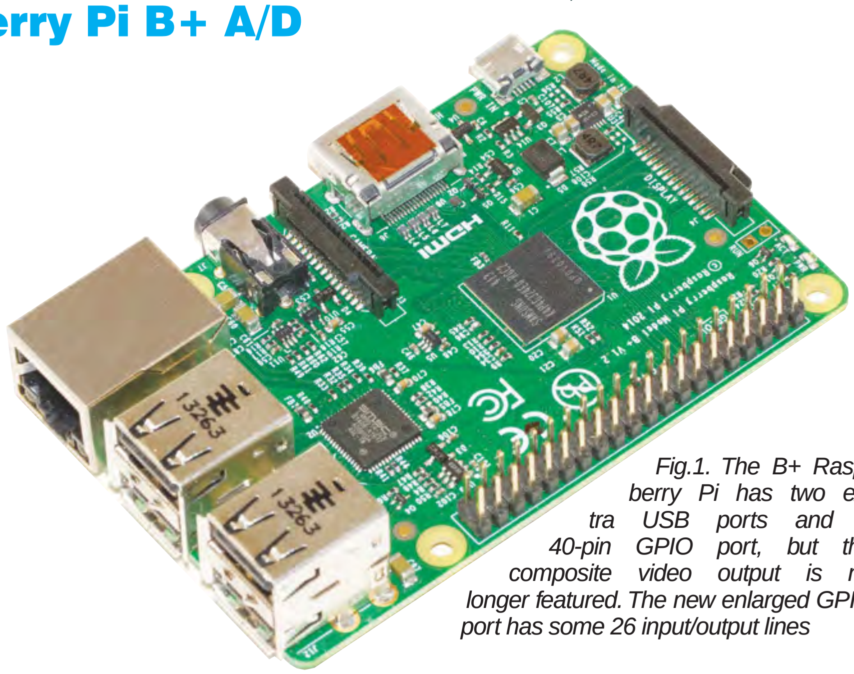


Fig.1. The B+ Raspberry Pi has two extra USB ports and a 40-pin GPIO port, but the composite video output is no longer featured. The new enlarged GPIO port has some 26 input/output lines

On the B+ side

First and foremost the board layout has been completely redesigned. Cases for the original boards are not suitable for use with a B+ board, but fortunately cases to suit the new layout are readily available. Fig.1 shows a Raspberry Pi B+ board, and one obvious change is that the composite video output has been omitted. I suppose that in this respect it is more of a 'B minus' board, but a composite video output is of little practical use these days.

On the plus side, there are now four USB ports as opposed to the two of the Model B board. With a mouse and a keyboard connected to two of these ports, there are still a couple left for such things as a card reader and a Wi-Fi adapter. This means that most users will avoid the need for a USB hub. In other respects, most of the ports are the same as before, but there have been improvements that give improved performance from the stereo audio output.

Another change to the hardware is that the SD card slot of the Model A and B boards has been replaced with a Micro SD card slot (Fig.2). This is a 'proper' card slot and not the simple friction type used on the earlier boards. One slight problem is that the multi-card readers fitted to many PCs, and the external USB reader units that can be obtained, do not usually have the ability to accept Micro SD cards. This could make it more difficult to produce your own boot card, but it is possible to obtain inexpensive adapters that enable Micro SD cards to be used with slots for standard SD cards. I produced a suitable boot disc using an MP3 player to act as a Micro SD card reader.

Some suppliers offer the Raspberry Pi with a boot card already installed. Rather than simply having the Raspian operating system preinstalled, this is now usually in the form of a NOOB (new out of the box) card. This contains the installation files for various operating systems that are compatible with the Raspberry Pi, and on running the computer for the first time there is a menu where the required system or systems are selected. It is then just a matter of going through the installation and setting up procedures. If more than one operating system is installed, a dual or multi-boot system is implemented, and the required operating system is selected from a menu each time the computer is started.

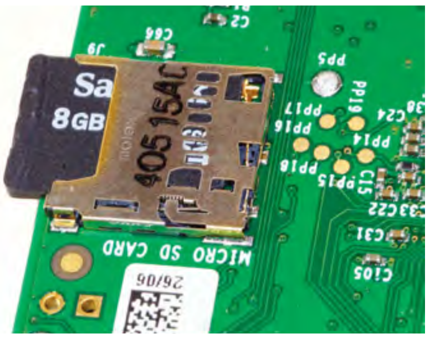


Fig.2. The simple SD card slot of the earlier models has been replaced with a micro SD type. This is spring-loaded, an improvement on the earlier friction slot

The Raspberry Pi is open source, and you can download the appropriate file and make your own NOOB boot disc. Remember that a 4GB card will not be sufficient, even if only the Raspian operating system is to be installed – the extra source files stored on the card means that an 8GB card is required. This should be sufficient to accommodate Raspian and at least one other operating system. Of course, a higher capacity card will provide more space for data storage, and could be advantageous when using some types of application software.

Best until last

The most important change for those using the Raspberry Pi with their own add-on devices is that the GPIO port has been expanded, and uses a 40-way connector instead of a 26-way type. The new scheme of things is shown in Fig.3, and the important point to note here is that pins from 1 to 26 have the same functions as before. It is possible to fit a 26-way connector onto these pins and use a Model B+ with hardware intended for the earlier versions. However, it is safer to use a 26-way cable that has a 40-way connector at one end and a 26-way type at the other, as this avoids the possibility of connection errors. These can be obtained readymade, but should not be difficult to make yourself.

Some extra input/output lines are provided by the additional pins of the

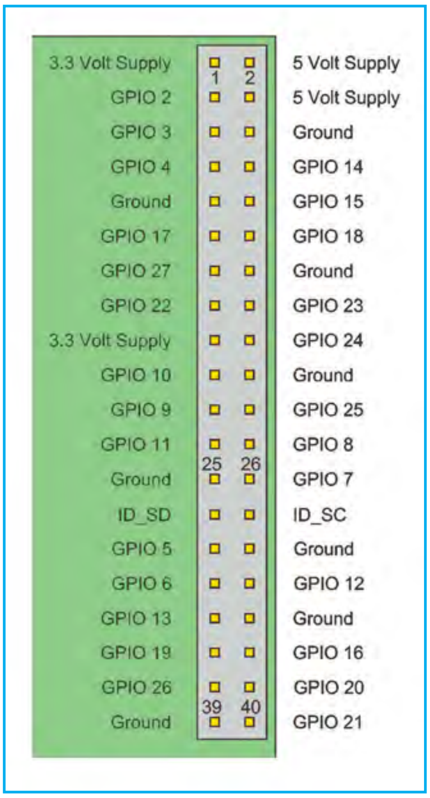


Fig.3. Details of the new enlarged B+ GPIO port. Pins 1 to 26 have the same functions as their equivalents on the original 26-way GPIO port, making it straightforward to use add-ons designed for use with the A and B models

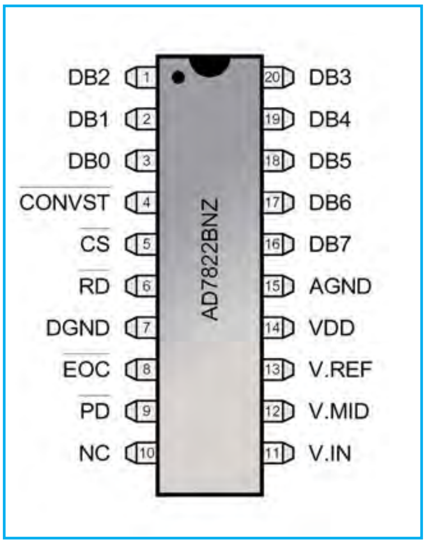


Fig.4. Pin functions for the AD7822BNZ 8-bit analogue-to-digital converter chip. It is primarily designed to interface to microprocessor buses, but it is easy to use it with the Raspberry Pi's GPIO port

expanded GPIO port. The ID_SC and ID_SD pins are for use with I²C interfacing and an EPROM. They should not be used for any other purpose, and are of no use for general interfacing. Some of the other new pins are ground terminals, but the remaining nine provide additional general-purpose input/output lines. As before, the GPIO numbering runs from GPIO 2 to GPIO 27, but with the expanded port there are no gaps in the numbering. This means that there are some 26 input/output lines on the B+ GPIO port. Even with parallel interfacing, this gives tremendous scope for adding your own devices to the port.

In order to use the new input/output lines with Python programs it is necessary to have the latest version of the GPIO add-on. Initially, I found that the new pins were unusable, even with the latest version installed. The problem seems to be that, as yet anyway, the add-on software does not support the new pin numbers, and using BOARD mode with numbers above 26 produces an error message. However, when using BCM mode the new GPIO numbers do seem to work, so at the moment it is strictly BCM mode if the full port is to be used.

Raspberry Pi A/D

A digital-to-analogue (D/A) converter for the Raspberry Pi has been featured in this series in the past, and here we move on to an analogue-to-digital (A/D) converter. I have tried 8-bit parallel and 12-bit serial types, and we will start with the former, which gave more consistent results. The parallel converter is based on an AD7822BNZ chip, which has a 20-pin DIL encapsulation and the pin-out configuration shown in Fig.3. It is a half-flash converter with a built-in sample and hold circuit, and its conversion time is 420ns. An integral 2.5V reference is provided, but an external reference voltage can be used if preferred.

This chip is primarily designed to interface to the buses of a microprocessor, but here it will be used with the ordinary digital input and output lines of the Raspberry Pi's GPIO port. Some of the control inputs are therefore largely irrelevant in the current context. The AD7822BNZ will operate on a 3.3V supply, which means it can interface with the GPIO port without the need for any level-shifting buffers. There are separate digital and analogue ground terminals at pins 7 and 15 respectively, but these are normally connected to a common 0V supply rail. DB0 to DB7 are the data bus outputs, and in this application they drive eight GPIO lines set to the input mode.

The /RD (Read) pin enables the tri-state data bus outputs when it is taken low, and it would normally be connected to the relevant line of the control bus. The same is true of the /CS (chip select) input, which deactivates all the outputs of the device when it is taken high. In this case, these inputs serve no useful function and are simply connected to the 0V supply so that the chip and all its outputs are permanently enabled.

The /CONVST pin is the start conversion input, and it is pulsed low to produce a conversion. The chip has an automatic power-down feature, which is really more of a hindrance than a help in the current context. The chip tends to go into the 'sleep' state before all its output lines can be read. This is avoided by supplying a low pulse to the /PD (power down) input at pin 9 before reading the data outputs. This sets the chip into the fully active mode until another conversion has been completed.

There is an /EOC (end of conversion) output at pin 8, and this goes low when a conversion has been completed. The

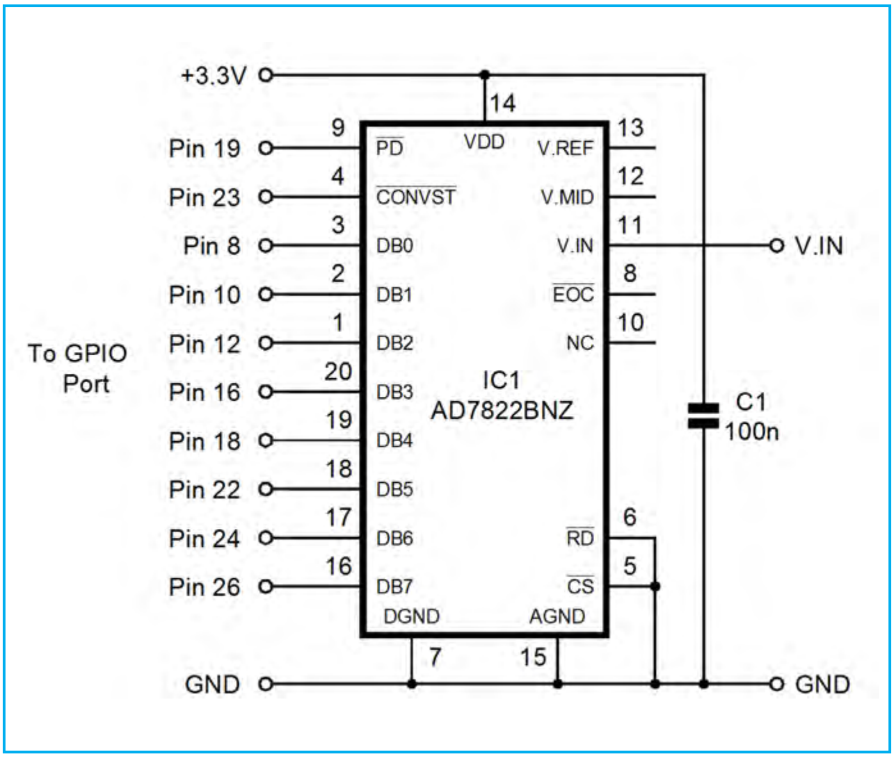


Fig.5. Circuit diagram for the parallel interface 8-bit analogue-to-digital converter. The internal 2.5V reference is used, and no connections are made to the V.MID and V.REF pins

data lines should not be read until this status output goes low, but the speed of a Raspberry Pi and a Python program is such that each conversion will be completed well before any of the data lines are read. Consequently, there is no need for a hold-off to be provided and the /EOC output is left unused.

A built-in in 2.5V reference has its output available externally at pin 13, and there is also a VMID input at pin 12. The latter enables an offset to be applied so that the input voltage span can be adjusted. In most applications this feature is not needed, and it will not be considered further here.

Software

The circuit diagram for the analogue-to-digital converter is shown in Fig.5. The unused control inputs are connected to the 0V supply, and the other pins that are not required here are simply left unconnected. Pins 19 and 23 of the GPIO port are used as outputs to control the /PD and /CONVST inputs of IC1. The data outputs of IC1 are connected to various inputs on pins 8 to 26 of the GPIO port. The internal reference voltage is used, giving the converter an input range of 0 to 2.5V (±2%), which equates to a resolution of just under 10mV. Of course, in a real-world application an attenuator or amplifier will be needed ahead of the converter to produce the required input voltage span.

The software routine of Listing 1 can be used to read the converter. The first two sections of the program set up the GPIO port and set the two output lines to the correct initial state (high). A `while… loop` is then used to read the converter 200 times. This number can be altered by changing the value in the first line of the loop, or the program can be made to loop indefinitely by removing the last line of the loop so that the variable called ‘count’ is not incremented. Four output instructions are used to generate the pulses that start each conversion and ‘wake’ the converter from its powered-down mode. The 8-bits of data are then read one-by-one, and assembled to produce the full byte of data in the variable called ‘byte’. This value is printed on the screen at the end of each loop.

Noise is not too much of a problem with an 8-bit converter, and the breadboarded prototype produced stable readings. It is only suitable for applications where low sampling rates are required, due to the relatively slow operating speed of the Raspberry Pi and the Python programming language. The converter chip is capable of about two million conversions per second!

Listing 1

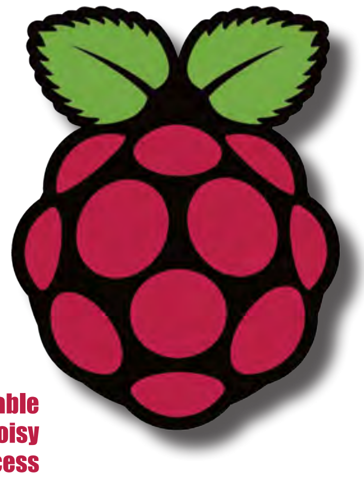
```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)

GPIO.setup(8, GPIO.IN)
GPIO.setup(10, GPIO.IN)
GPIO.setup(12, GPIO.IN)
GPIO.setup(16, GPIO.IN)
GPIO.setup(18, GPIO.IN)
GPIO.setup(22, GPIO.IN)
GPIO.setup(24, GPIO.IN)
GPIO.setup(26, GPIO.IN)
GPIO.setup(23, GPIO.OUT)
GPIO.setup(19, GPIO.OUT)
GPIO.output(23, GPIO.HIGH)
GPIO.output(19, GPIO.HIGH)
count = 0

while (count < 200):
    GPIO.output(23, GPIO.LOW)
    GPIO.output(23, GPIO.HIGH)
    GPIO.output(19, GPIO.LOW)
    GPIO.output(19, GPIO.HIGH)
    byte = 0
    if GPIO.input(8):
        byte = byte + 1
    if GPIO.input(10):
        byte = byte + 2
    if GPIO.input(12):
        byte = byte + 4
    if GPIO.input(16):
        byte = byte + 8
    if GPIO.input(18):
        byte = byte + 16
    if GPIO.input(22):
        byte = byte + 32
    if GPIO.input(24):
        byte = byte + 64
    if GPIO.input(26):
        byte = byte + 128
    print (byte)
    count = count + 1

GPIO.cleanup()
print ("Finished")
```

RPIADCISOL from Zeal Electronics



Mike Tooley, *EPE's* resident Raspberry Pi expert, takes a look at the first commercially available optically isolated 24-bit ADC board for the Pi. Designed specifically for use in 'harsh' and noisy industrial environments, this board offers a wealth of features and also provides optically isolated access to the Pi's GPIO port lines.

The RPIADCISOL is one of several high-performance optically isolated interface boards for the Raspberry Pi from Zeal Electronics Ltd. The optical isolation eliminates problems that would normally be associated with measuring analogue voltages at different potentials above or below the ground potential of the Raspberry Pi. This is important in a number of applications, for example monitoring mains supplies, motor currents, bus bars, and general-purpose use when sensors and transducers need to operate or float above ground potential.

The RPIADCISOL interface is suitable for connecting to all current versions of the Raspberry Pi, including models A, B and B+, as well as the new single-card industrial Raspberry Pi Compute Module. The Compute Module contains the Raspberry Pi's BCM2835 processor, together with 512MB of RAM and 4GB of Flash memory (equivalent to the Pi's SD card). The RPIADCISOL is also eminently suitable for connecting to any microcomputer system that has an SPI interface, such as Microchip PICs and Atmel.

The simplified block schematic of the RPIADCISOL is shown in Fig.2. The ADC is a Microchip MCP3913, which can sample at up to 125k samples per second with up to 24-bit resolution. In conjunction with the six-channel ADC, the board provides four galvanically isolated differential 24-bit ADC inputs and two differential 24-bit non-isolated ADC inputs (±600mV range). The isolated ADC channels have a range of ±150mV range, while their non-isolated counterparts provide a range of ±600mV.

A very useful feature is that, by using four quad ISQ203 optical isolators, the RPIADCISOL provides an additional eight optically isolated digital inputs and eight optically isolated digital outputs. As with the optically isolated analogue channels, these digital I/O lines provide total isolation from ground potential. In addition, the eight digital outputs are also available in non-isolated open-collector form. This makes them ideal for driving loads, such as relays and motors that require currents of up to 1A from a +5V supply.

These digital I/O lines are directly accessible through the Raspberry Pi/s standard GPIO interface and so they don't need to use the slightly more complex SPI commands. This makes the digital I/O lines very easy to use, but with the added advantage of optical isolation that's not present on a 'barefoot' Raspberry Pi board. This bonus feature is a distinct advantage because it could save you having to purchase a separate digital I/O board!

Depending on how the GPIO ports have been configured, the digital interface has been designed to enable the GPIO lines to be set for use as either inputs or outputs, thus providing maximum flexibility. As an example, three GPIO port lines could be configured as inputs, while the remaining five GPIO ports lines could be configured as outputs. The input and output optical isolators used for the eight digital inputs and eight digital outputs have a reasonably fast turn-on time of 3μs and a turn-off time of 2μs. This makes them ideal for signals that are rapidly changing.

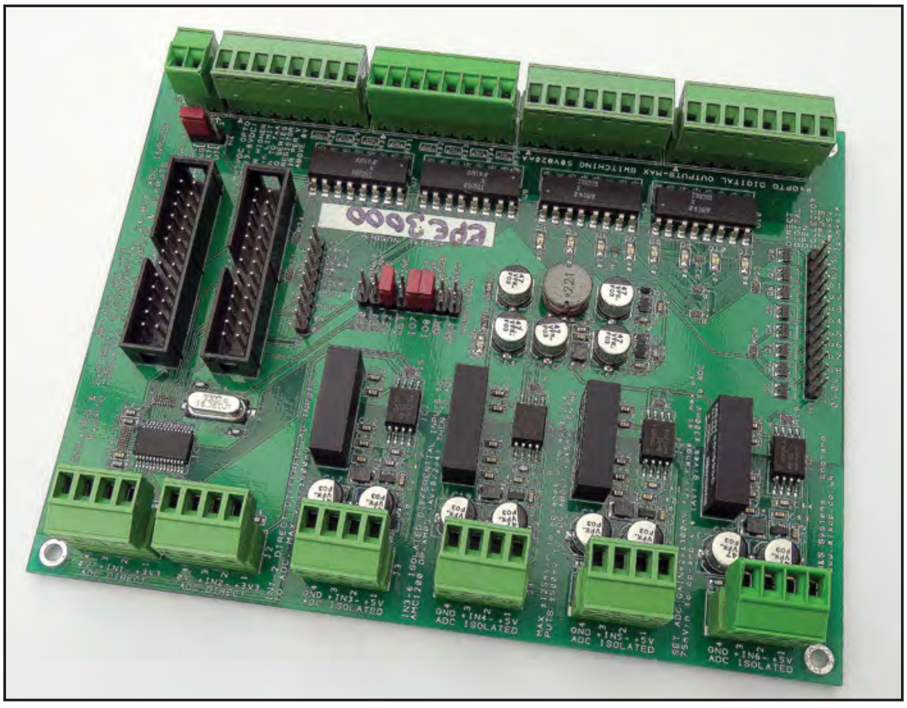


Fig.1. General view of the RPIADCISOL 24-bit optically isolated ADC board

Optical isolation

RPIADCISOL offers several features that make it ideal for a wide range of control, monitoring and sensing applications. Most notable among these is the use of optical isolators, which provides a very effective means of preventing high voltages from circuits being switched or monitored causing damage to a host computer such as the Raspberry Pi.

A typical situation in which optical isolation could be vital is control of high-voltage switching devices and sensing currents on supply bus bars. Without optical isolation, the host computer could easily be destroyed. Optical isolation also reduces the likelihood of impulse voltages and spikes getting back into the host computer and safeguards against the effect of ground loops, which can introduce noise and offset voltages onto the relatively small signal levels associated with many types of sensor. Isolation is thus an essential requirement whenever sensitive electronic equipment like the Raspberry Pi is used in electrically harsh environments such as those found in industry.

Board specification

Analogue inputs
Two directly coupled differential 24-bit ADC inputs, ±600mV max. (Inputs 1 and 2)
Four optically isolated differential 24-bit ADC inputs, ±150mV max. (Inputs 3, 4, 5 and 6)
Four AMC1200 isolated op-amps are used to provide isolation for Inputs 3, 4, 5 and 6 with a bandwidth of up to 60kHz. Voltage isolation (input ground to board ground) 1kV max.

Sensor supplies
Inputs 1 and 2 have +3.3V (non-isolated) at 50mA available to power external sensors.
Inputs 3 to 6 have +5V (isolated) at 50mA available to power external sensors.

Digital inputs
Eight optically isolated digital inputs (3V to 8V max.)

Digital outputs
Eight optically isolated digital outputs (for switching 50V at 20mA max.) and eight direct (non-isolated) outputs via NMOS transistors (for switching 5V at up to 1A)

Interface
Standard Raspberry Pi GPIO for digital I/O and high-speed SPI interface with Mode 0,0 and 1,1 compatibility

Dimensions
142.5 × 110mm (with approx 20mm clearance above the board)

Mounting
Four 3mm mounting holes at 134.5 × 102mm

Connectors
All inputs and outputs are via 3.5mm industrial plug-in screw terminal connectors. The Raspberry Pi is connected via a standard 26-way GPIO ribbon connector

Power supply
+5V at 200mA (directly from the Raspberry Pi +5V bus or from external +5V supply).

Layout and circuit features

The general board layout of the RPIADCISOL is shown in Fig.3. The layout is both logical and convenient – all the off-board connectors used for input and output are located along the two opposite edges of the board. The two 26-way GPIO bus connectors along the third side of the board provide a means of daisy-chaining the GPIO signals to/from the Raspberry Pi. The remaining side of the board provides access via a single in-line connector to the open-collector digital outputs (see Fig.4). The external power supply links and external power connector are located at the top right of the board. Note that if using an external +5V power supply it must be rated at a minimum of 200mA.

Various configuration options can be set by means of a link header near the centre of the board. Depending upon the application, the configuration links should be set before use. These include the four chip enable (CE) lines (note that the board is supplied with the default CE2 link in place). In addition to the chip enable links, there are also interrupt function links (INTA and INTB for IO7 and IO8 respectively) and reset (RST).

When using other computers or microprocessors, eg Microchip PIC devices, their SPI interfaces can be connected to the Aux SPI Connector, which is located between the configuration link header and the GPIO connectors. This connector must not be used when the RPIADCISOL is already connected to a Raspberry Pi with the 26-way GPIO cable, otherwise the GPIO ports could be damaged. The Aux SPI connector provides access to the SPI lines, including MISO, MOSI, SLCK and CE. Connections are also available for the +5V and +3.3V supply rails.

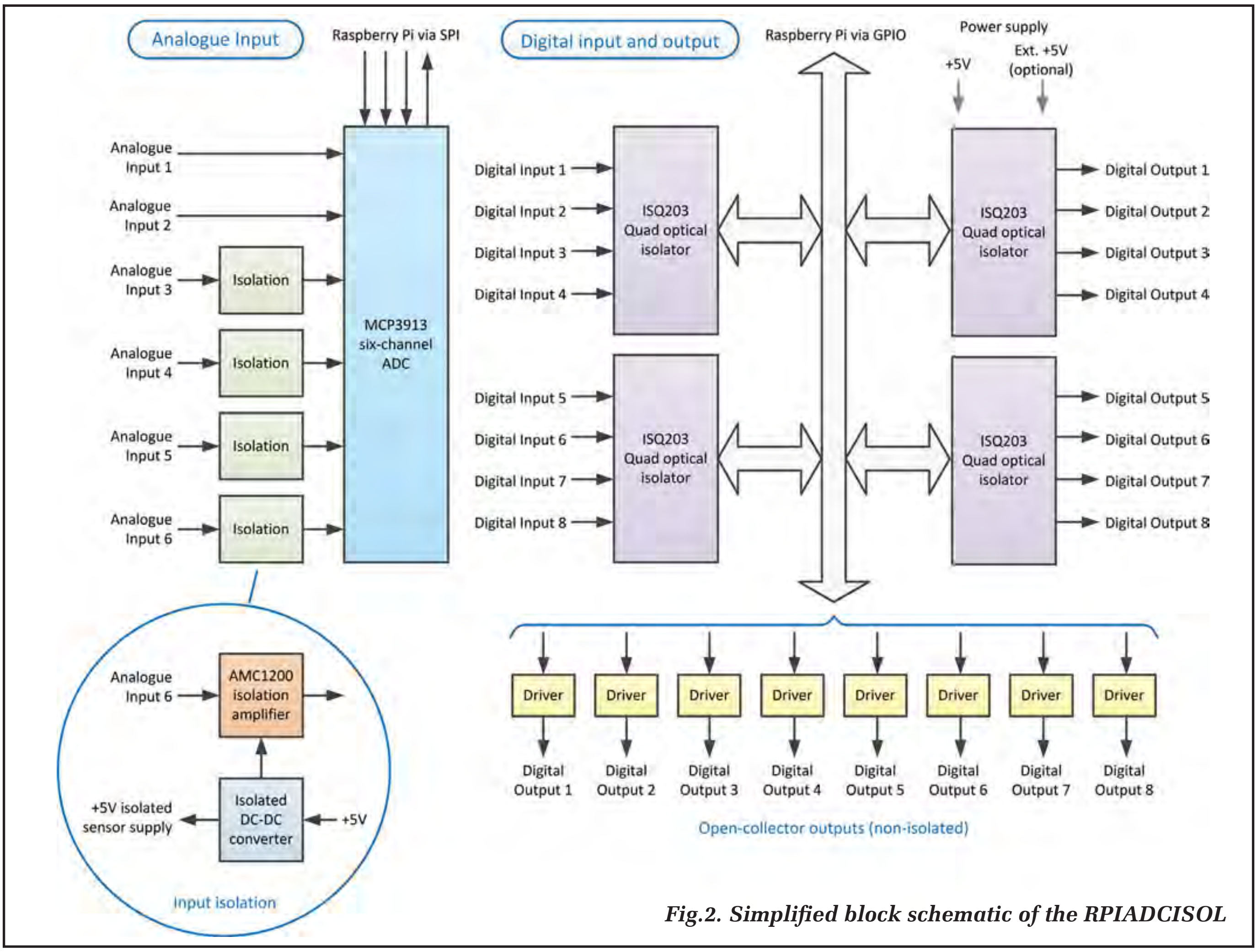


Fig.2. Simplified block schematic of the RPIADCISOL

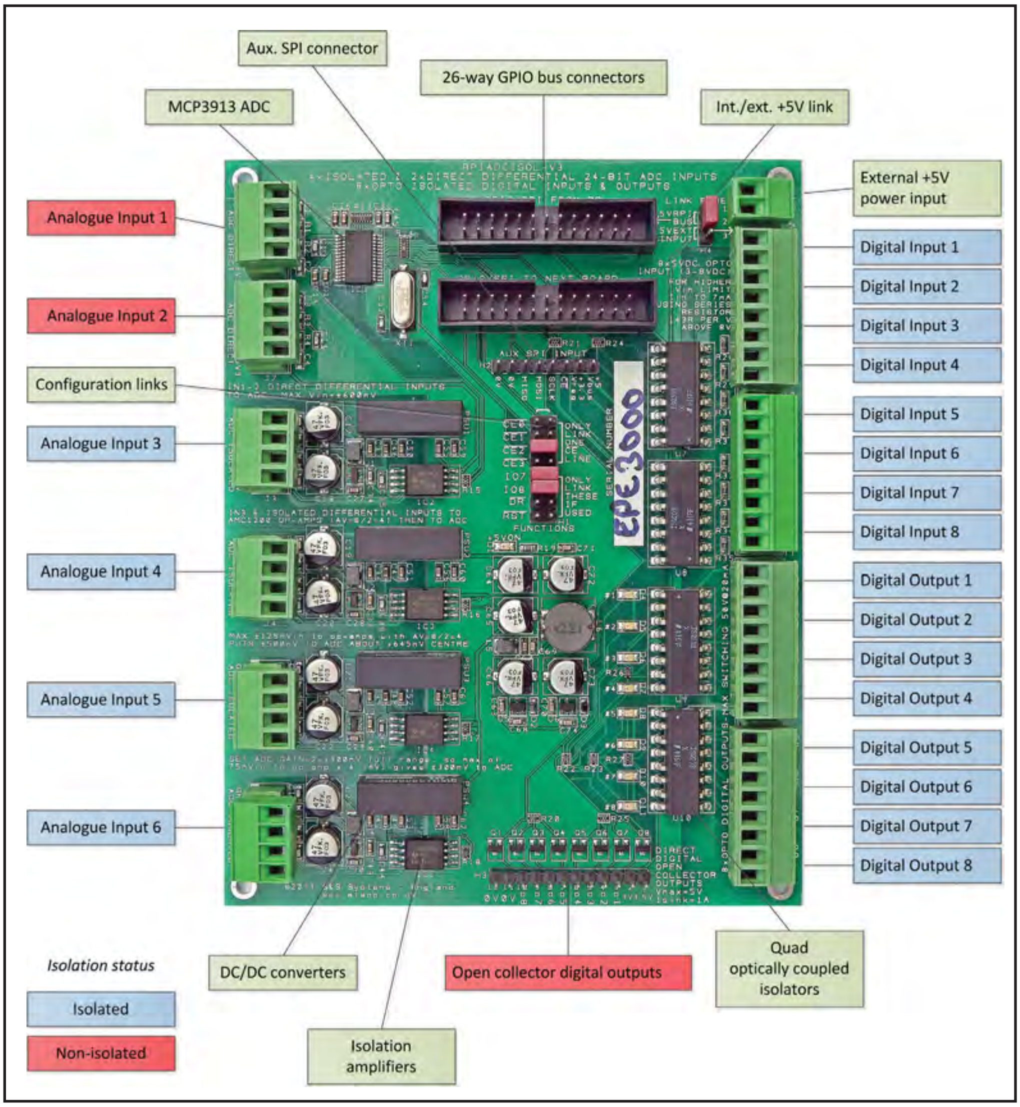


Fig.3. RPIADCISOL board layout

The manual assumes that the reader has some familiarity with the C-programming language and, while C is a somewhat more obscure and prescriptive programming language than either BASIC or Python, a simple web search will provide a beginner with access to a vast repository of information, tutorials and example code.

The board is most conveniently programmed using the Raspberry Pi's own built-in C compiler, GCC. Leafpad (or an equivalent text editor) will be required to write and edit your C source code, but all of the other files needed to compile an executable program are supplied with the RPIADCISOL. They include header files for the chips used on the board (BCM2835 and MCP3913) together with a sample C program and an associated make file. The code supplied can be freely used in any non-commercial applications, within education, and for home use as per the standard GNU v2 open source license. The source code files are efficient and commented in such a way as to make them easy to use and understand. Newcomers to C-programming should have little difficulty in getting to grips with them.

On test

Being a coward (and not wanting to subject my Raspberry Pi B+ to 'death by high-voltage'!) it was with some trepidation that I set about connecting the RPIADCISOL to my high voltage DC power supply. To conduct the tests I used some simple code to read the output of a sensor connected to the differential input of one of the isolated ADC channels with the high-voltage supply connected between sensor ground and board ground (ie, the 0V rail of my Raspberry Pi).

Throughout the tests, I kept my code running on the Pi with the sensor providing a continuous analogue input signal to the ADC channel and the value returned from it displayed on the monitor screen courtesy of a simple loop coded in C. The value displayed remained rock solid while I first applied 50V DC, then slowly increased this to 350V DC and finally to 400V DC. Next, I tested the board with 30V, 50V and 110V AC, before finally applying 400V DC *in series with 110V AC*, giving a peak voltage on the sensor ground of a little under 550V above the true ground potential of the Raspberry Pi. Amazingly, I noticed absolutely no change in the displayed reading while all this was going on. To say I was relieved (and impressed) is an under-statement!

The digital inputs and outputs were also tested. These behaved predictably when used with some simple C code and I was able to read digital data and then write it to the outputs with no difficulty whatsoever. During these tests I found the eight on-board LEDs to be particularly useful for telling me what was going on.

GPIO protection

The RPIADCISOL has digital outputs that are current limited by means of a fixed series resistance of 2.2kΩ. This helps to avoid the situation that might occur when an input optical isolator has been initially turned 'on' or 'off' and then the same line is inadvertently set to 'on' as an output. The series resistance has the effect of limiting the current from an individual GPIO line to around 1.5mA. Note also that if your application simply needs optical isolation between inputs and outputs without the need for any programmed control, it is possible to set the appropriate GPIO lines as inputs and then not bother to read them. The logical state of the optically isolated inputs can then be passed directly to the respective outputs. This provides further flexibility and might be useful where, for example, optically isolated switching is required without the need for Raspberry Pi programmed control.

Connectors

Having tried and tested many interface boards for the Raspberry Pi, one factor that makes some boards stand out compared to others is the relative ease of making off-board connections. The RPIADCISOL does this rather well, as it uses standard industrial 3.5mm PCB-mounted headers with connectors that are fitted with screw terminals. This makes prototyping blissfully easy because connectors can be quickly and easily removed from the board and there's no need for any soldered connections.

Documentation and example code

The RPIADCISOL is supplied with a detailed 86-page manual that provides full information on installing, connecting, using and programming the range of boards designed and developed by Stephen Alsop and available from Zeal Electronics.

Other products from Zeal Electronics

In addition to the RPIADCISOL, Zeal Electronics also supplies two other high-specification optically isolated interface cards designed specifically for the Raspberry Pi. These boards can be 'daisy chained' onto the Pi's GPIO bus and can be connected to the 26-way GPIO expansion connector on the RPIADCISOL to provide an extended digital I/O capability with 16 channels

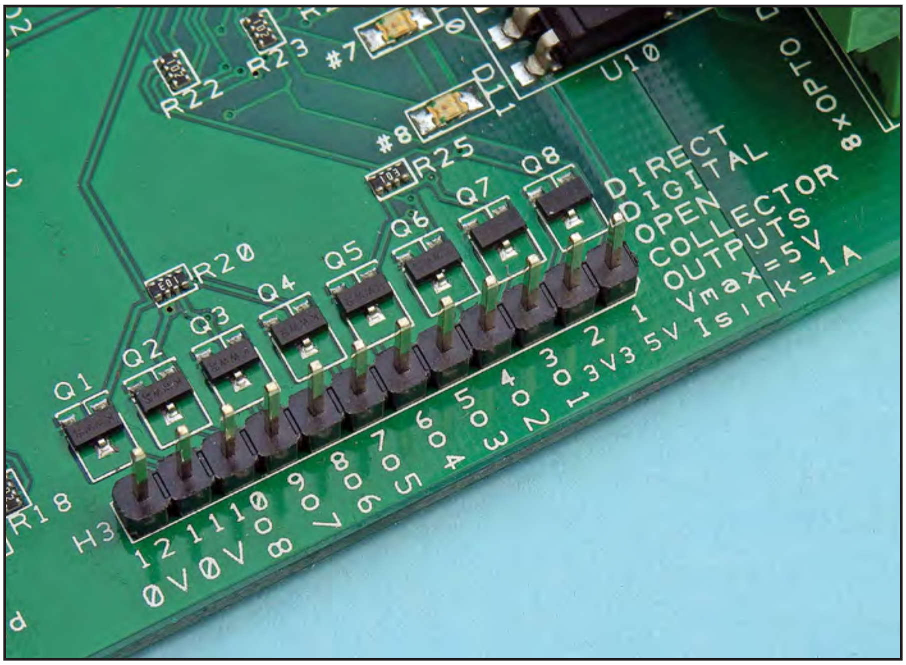


Fig.4. The board has eight additional open-collector digital outputs

up to a maximum of 128 inputs and 128 outputs from eight daisy-chained boards of each type. We will be taking a detailed look at these products in a future issue of *EPE*.

Pricing

Priced at a little over £100 (with 10% discount for *EPE* readers) you might at first think that the RPIADCISOL is a little on the expensive side. However, this board offers features that others don't and the very high degree of isolation of four of the six ADC inputs doesn't come cheap. Couple this with the eight additional optically isolated digital inputs and outputs and you realise this board represents good value. If you don't believe me, take a look at the cost of the high specification isolation amplifiers that the board uses. Go and purchase four isolated AD215AY devices from one of the most popular UK component suppliers (without the PCB, eight-channel ADC, four isolation power supply units and additional optically isolated digital I/O) and the bill would come to a whopping £246 – without VAT!

Conclusion

If you are working in an environment where a very high degree of isolation is critical then have no fear – this board will deliver. The RPIADCISOL offers an excellent specification and is well supported with liberally commented source code. Under test, the board performed exceptionally well and readers with only limited C programming experience should be able to get the board up and running quickly and easily. The interface represents good value and is ideal for use in a wide range of applications where sensors and transducers are not at true ground potential.

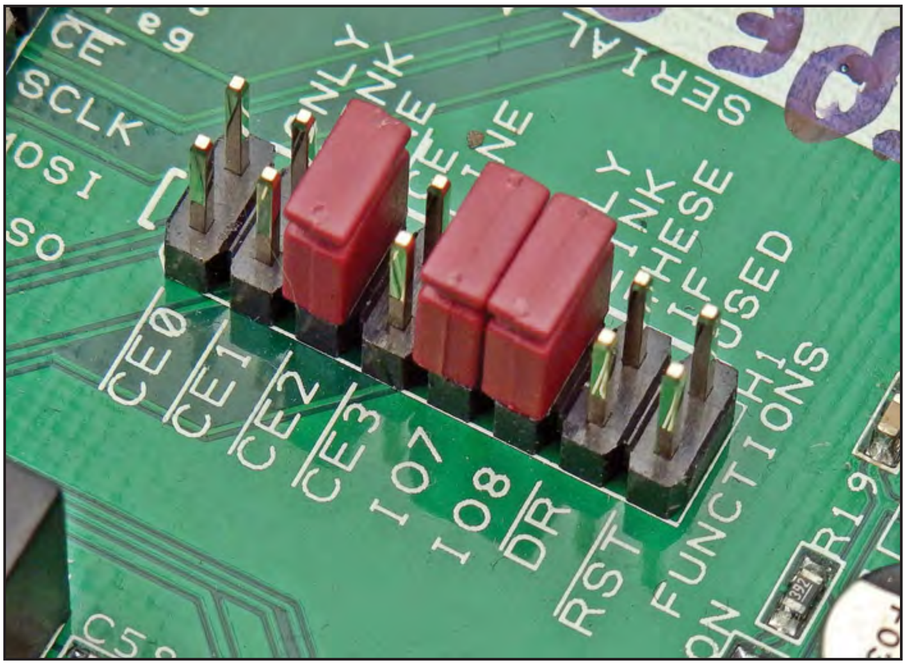


Fig.5. Configuration links

BY IAN BELL

Power MOSFET failures

EPE *Chat Zone* user ***miketuk*** posted the following question concerning problems with failing Power MOSFETS.

I have built the Solid State Valve PSU from the Dec' 2005 EPE. *It uses a 74HC04 to drive two IRF530 FETs in a push-pull manner to generate a square wave, which is then stepped up with a 12-0-12/240V transformer. The output is rectified and smoothed to give ~ 200V DC for the HT voltage. However, the IRF530 FETs keep going up in smoke (not literally). They are protected with a 33V Zener across the drain-source, so I can't understand what is happening to them. I am running from a current-limited desktop PSU to give the input voltage of 12V. Current is below 100mA. I would point out at this point there is no load across the HT line. Any advice before I go out and buy another batch?*

Other *Chat Zone* users posted plenty of suggestions and discussion, as they often do, and ***miketuk*** tentatively reported a working circuit a week or so later. Power MOSFETs are devices that, perhaps more than many other components, tend to fail during prototyping, often without immediately obvious and straightforward causes (such as errors in wiring). The fact that they may be handling large currents and voltages means that the failures can be spectacular (you may even get smoke, unlike ***miketuk***). In this month's *Circuit Surgery* we will take a general look at the causes of power MOSFET failure and some approaches to preventing these problems.

MOSFET overview

We looked at the basics of MOSFETs a few months ago. As a reminder, the cross section of a generic N-channel MOSFET is shown in Fig.1 (not a power device). Strictly speaking, the device has four terminals: gate, source, drain and bulk. The bulk and source are often connected together within the device structure, resulting in the familiar three-terminal discrete component with just gate, source and drain connections.

The simplest view of MOSFET operation is as a switch, with the gate voltage controlling conduction from source to drain (on or off). Power devices are most commonly operated as switches because this allows high power levels to be controlled without incurring excessive dissipation in the device. With a small, zero, or negative gate voltage (with respect to source/bulk) the N-channel MOSFET will not conduct from source to drain in either direction. This is because the PN-diode junctions between source and bulk, and between drain and bulk will be surrounded by a non-conductive depletion region (like a reverse-biased diode). This non-conducting mode of operation is called the cut-off region. Similarly, a P-channel MOSFET will be cut-off with small, zero, or positive gate voltage.

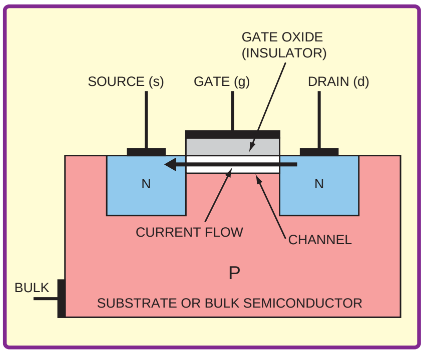


Fig.1. Cross section of N-channel MOS-FET

Applying a positive voltage to the gate of an N-channel MOSFET (with respect to source/bulk) will attract electrons to a region directly under the gate. If the density of these electrons is sufficient they will outnumber the holes from the P-type bulk semiconductor, transforming it into N-type. At this point we have an N-type channel from source to drain (see Fig.1) which bypasses the PN-junction depletion regions and allows conduction between source and drain. The gate voltage at which the conducting channel forms is called the threshold voltage, V_T. Similarly, a P-channel MOSFET will conduct with negative gate voltage (with respect to source/bulk) which is greater than its threshold.

Power MOSFET architecture

When a MOSFET is used in a switching application it is switched between fully on and fully off, by switching the gate-source voltage between 0V and some voltage well above the threshold. Use of voltages well above threshold ensures saturated operation, in which the ON-resistance ($R_{DS(ON)}$), the voltage drop across the device, and power dissipation are minimised. We can consider the device to be either in the *off* state, where little or no power is dissipated, or the *on* state, where power dissipation depends on $R_{DS(ON)}$ and the drain-source current. Low $R_{DS(ON)}$ is therefore important in minimising power dissipation and is particularly important for devices handling large currents.

Making a MOSFET with the physical layout of the device shown in Fig.1 is not easy for high-power devices – it is difficult to make the cross-sectional area of the conducting region large enough. If this area is too small then $R_{DS(ON)}$ will be too high, resulting in excessive power dissipation when conducting large currents. The basic solution is to use vertical current flow. The devices can have either flat (planar) gates, as shown in Fig.2, or use groove or trench structures, as shown in Fig.3. Terms such as 'trench' and 'deep gate' occur in MOSFET product names to reflect the shape of these structures.

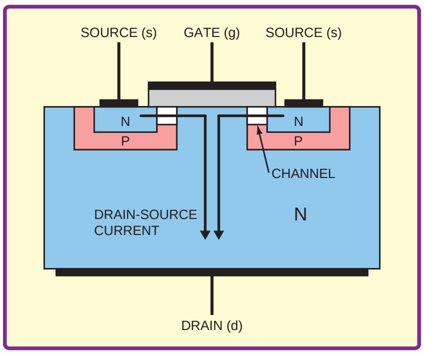


Fig.2. Simplified planar-style power MOSFET structure, showing vertical current flow

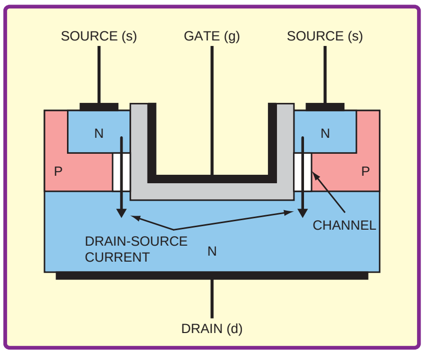


Fig.3. Simplified trench-style power MOSFET structure, showing vertical current flow

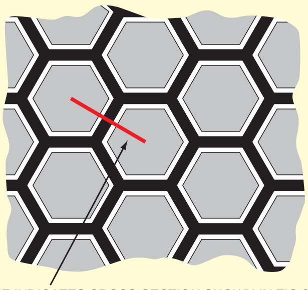


Fig.4. Top view of MOSFET design using hexagonal repeated cells to form parallel transistors. The grey areas form the source and black areas are the gates

Discrete MOSFETs can be connected in parallel to provide higher current handling capability (effectively reducing $R_{DS(ON)}$). Paralleling MOSFETs is exploited by device manufactures to enhance device performance. Many transistors are created in parallel in silicon to give high current capability. A variety of shapes can be used for these repeated structures, including strips, squares, triangles, or, as illustrated in Fig.4, hexagons (HEXFET is a name used by International Rectifier,). Some power devices have many thousands of parallel transistor cells.

Static discharge

Before looking at circuit-related causes of failure, it is worth mentioning that MOSFETs are liable to damage by static electrical discharge. This often happens when someone whose body has acquired a charge handles the device. Component damage can be avoided by correct handling (storing the device in anti-static packaging and avoiding touching the leads). Grounded wrist straps and grounded conductive bench mats should be used if static electricity is a particular problem.

Device maxima

Power MOSFETs, like all components, have absolute maximum rating for voltages, currents and power dissipation. It is relatively straightforward to make sure these are not exceeded in terms of basic circuit parameters. For example, in Fig.5 the supply must not exceed the maximum drain-source voltage (V_{DS}) and the current given by the supply voltage divided by the load resistance must not exceed the maximum continuous current rating. Similarly, the output voltage of the drive circuit must not exceed the maximum gate-source voltage. Even very short over-voltage pulses can destroy MOSFETs, so it is best not to operate them on supplies/driving too close to their limits if possible.

The characteristics of loads need to be understood. Some loads, such as motors, will not present a constant load, so the worst-case current demand must be within the MOSFET's capabilities. An

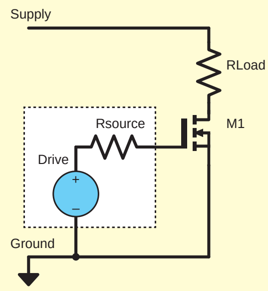


Fig.5. MOSFET switching a load

issue with some loads is that very high currents flow briefly when they are first switched on (known as inrush current), this must not exceed the device's drain current limit.

The continuous power dissipation when the device is on is given by:

$$P_C = I_D V_{DS} = I_D^2 R_{DS(ON)}$$

This must be within the device's capabilities, taking into account any heatsinking used. Insufficient gate voltage can result in damage to the MOSFET. If the MOSFET is not fully turned on then the resulting relatively high $R_{DS(ON)}$ will cause high power dissipation.

The continuous voltage, current and power ratings are not the complete story, because often MOSFETs will be being switched on and off (at high speed in many application). During the switching process, transient effects occur that may cause the device's ratings to be exceeded, even if the basic conditions just described seem to be well within its capabilities – consider the capacitance at the device's gate.

Gate capacitance

Fig.1 to 3 show that the gate, gate oxide and channel form a conductor-insulator-conductor structure – in other words, a capacitor. This means that no current flows into the gate if its voltage remains constant so the gate is sometimes simply assumed to be an open circuit. However, for high-power devices the gate capacitance may be large and this can have a significant impact on circuit performance and may well play a role in device failure.

In order for power MOSFETs to switch quickly and efficiently, sufficient current must be available to quickly charge or discharge the gate capacitance of the device. The gate capacitance and the driver circuit's source resistance and the resistance of the wiring (inside and outside the device) result in the gate voltage following an RC charging curve. The significance of this is that the MOSFET will spend some time between being fully on and fully off. During this time the device may dissipate a lot of power, a problem referred to as 'switching losses'. This *must* be taken into consideration when working out the total power dissipation. Excessively slow switching may cause damage.

It also follows from this that the drive circuit must be able to supply enough *transient* current to charge the gate capacitance at the required rate. In some cases, this current may be quite substantial, particularly for large very high power devices, or where paralleled MOSFETs are being used.

The effective capacitive of the MOSFET gate and hence the drive current required is increased by the Miller effect. This occurs when a capacitor is connected to produce negative feedback in an amplifier – the gate-drain capacitance in this case. The capacitance is multiplied by a factor related to the amplifier gain to give increased *effective* capacitance. The dynamic capacitance of power MOSFET gates during switching is complex and can be difficult to analyse. The net effect is that driving the power MOSFET gates is probably harder than it first looks – hence the need for good driver circuits.

Inductive loads

A well-known potential cause of power transistor failure is excessive drain-source voltage that can occur when switching inductive loads, such as relays, solenoids and motors. A basic scenario is illustrated in Fig.6. When current in an inductive load is switched off, the magnetic field, which had been established by the supplied current, collapses, inducing a voltage known as the 'back EMF' or 'inductive kick'. This may result in voltages large enough to damage or destroy the MOSFET. The more rapid the change in current as the inductor is switched off, and the larger the inductor value, the greater the back EMF generated.

Protection diode techniques

The usual method of preventing the back EMF from causing problems is to place a protection diode across the inductor, as shown in Fig.7 (D1). This diode is reverse biased when the power switching device is on, but is forward biased by the back EMF; so the diode dissipates the power or feeds it back to the power supply. Obviously the protection diode must have sufficient

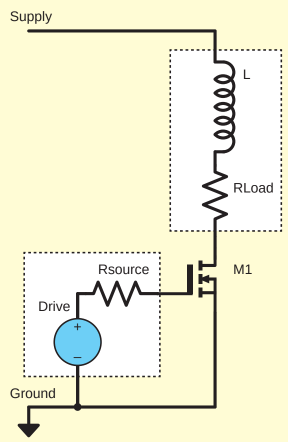


Fig.6. MOSFET switching an inductive load

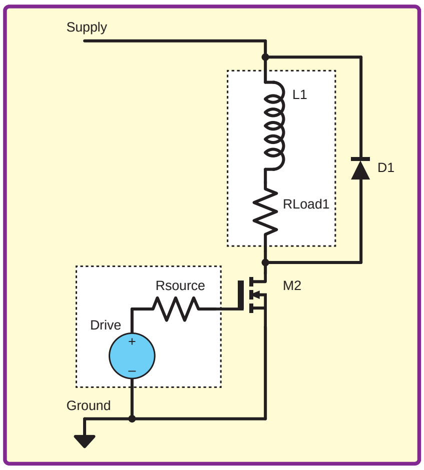


Fig.7. Protection diode

switching speed, and power handling capacity, to cope with the energy from the back EMF.

Fig.8 shows some simulated waveforms from circuits like those in Fig.6 and Fig.7. The specific components and values here are not important – they will vary significantly in different applications anyway – it is the general shape of the waveforms which is of interest. The first waveform is the drive signal, which is switching the device from on to off in the waveform shown.

In the second waveform, we see the back EMF, the voltage spike produced by the inductor when it is switched off by the MOSFET. In this case it is around 20V (four times the supply voltage), but can easily be much larger in real applications. The simulation was set up to keep the spike reasonably small so that the final drain voltage could easily been seen on the graph. The back EMF appears as a positive voltage spike at the drain of the MOSFET. If this voltage is large enough it will cause breakdown to occur in the transistor and high current will flow, possibly damaging the device.

The third waveform in Fig.8 shows the same circuit, supply and input drive conditions, but with a protection diode in place, as shown in Fig.7. When the back EMF is generated, a small overvoltage of around 1V occurs at the drain – the turn on voltage of the diode. The final waveform shows the diode current, which indicates when it is conducting to suppress the back EMF spike.

Cable inductance

A diode may provide effective protection against back EMF from inductive loads such as relays; however, in some situations the wiring can have significant inductance, particularly if long wires are run to the load or power supply. The wiring inductance will also produce back EMF, for which the diode across the load will not provide any protection. The ideal solution is to reduce the inductance of the wiring by keeping it a short as possible and minimising any loops around which currents are flowing. If it is not possible to reduce the wiring inductance sufficiently, one protection approach is to use a clamping Zener across the MOSFET's drain and source, as shown in Fig.9. A snubber circuit (and resistor and capacitor in series across the MOSFET) can also be used, but it is less efficient (in terms of power consumption) and may slow down the load switching.

Multiple MOSFET circuits

MOSFETS are often used in combinations such as the push-pull circuit shown in Fig.10 and H-bridge circuits. In these applications further potential failure processes arise. For the circuit in Fig.10, and similar arrangements, it is essential that both transistors are never on at the same time. If this does occur, then there is effectively a short circuit across the supply and very large currents can flow – a condition known as shoot-through. This can destroy the MOSFETs. Shoot-through is avoided by design – make sure that the drive control circuit inserts a delay (dead time) between switching one transistor off and the other on.

In multiple MOSFET switching circuits such as Fig.10, the drain of a switched-off transistor can experience very large and fast voltage changes as other transistors switch. This can cause problems because of the drain-to-gate capacitance inherent in all MOSFETs (see Fig.11). The current through a capacitor is proportional to the rate of change of voltage across it, so a fast change in drain voltage in the circuit in Fig.11 will cause a current to flow in C_{gd1} of M1. This current can then flow through the MOSFET's internal gate connection resistance, the wiring resistance and driver source resistance producing a voltage drop. The result is a voltage spike on the gate of M1.

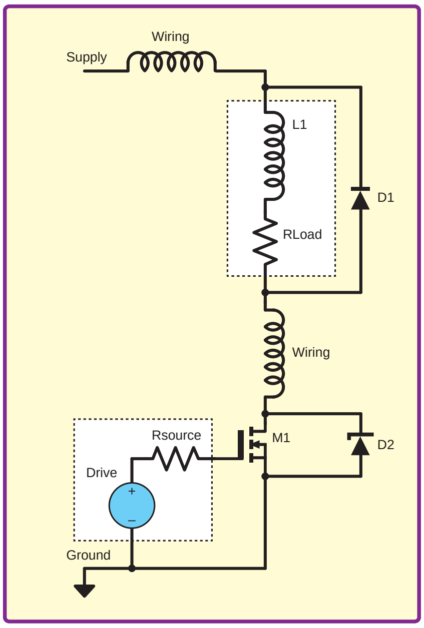


Fig.9. The protection diode (D1) does not cover wiring inductance. A zener clamp (D2) can help protect the MOSFET from back EMF from wiring inductance

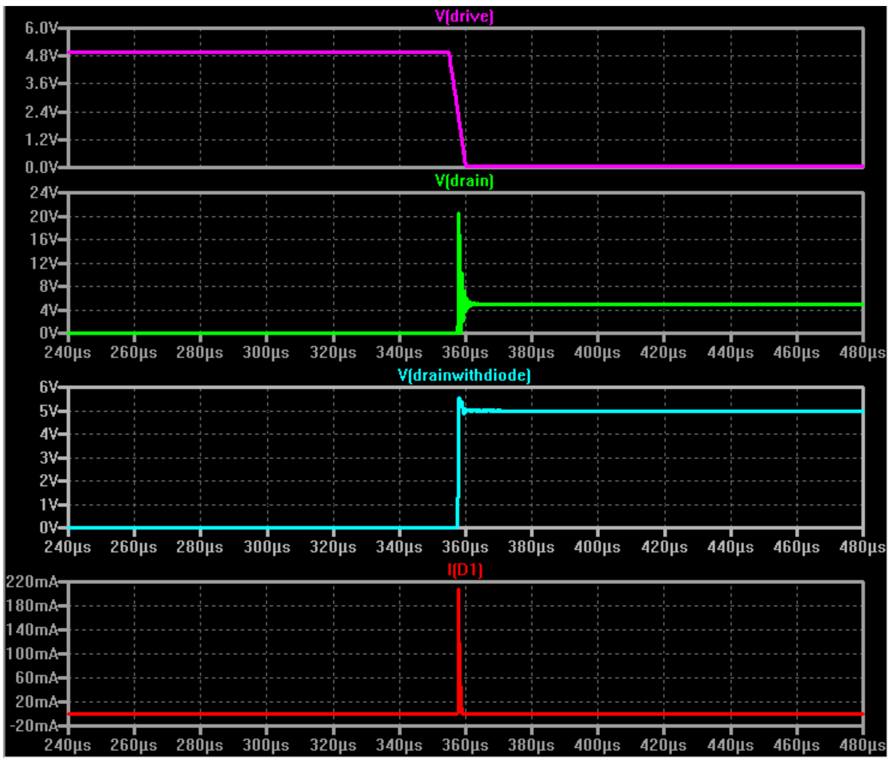


Fig.8. Illustrative waveforms for the circuits in Fig.6 and Fig.7

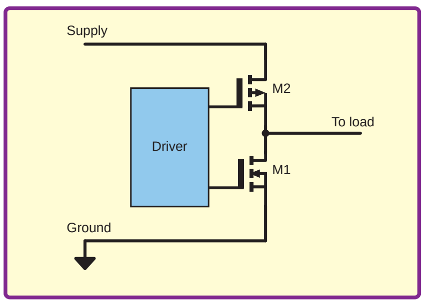


Fig.10. MOSFET push-pull circuit

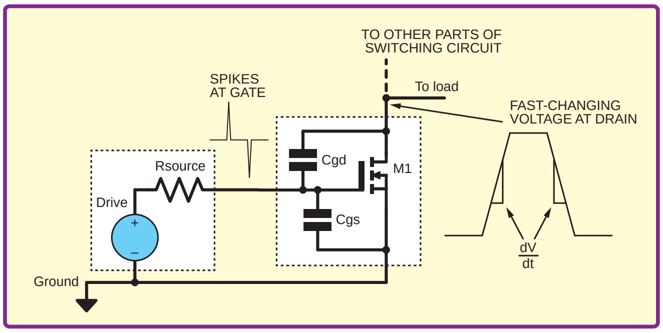


Fig.11. MOSFET capacitances which may contribute to drain dV/dt-induced damage

The spike on the gate may be positive or negative going depending on the direction of change of the voltage at the drain, and may cause damage via a couple of mechanisms. If the voltage spike is large enough it may simply exceed the maximum gate voltage and damage the MOSFET's gate oxide. A less excessive spike in the relevant direction (positive in the circuit in Fig.11) may turn the device on when it should be off, resulting in a shoot-though condition, and again possible damage.

This type of issue is referred to using terms such as dV/dt stress and dV/dt-induced turn on. 'dV/dt' is a differential, or 'rate of change' expression, in calculus. A full analysis of this phenomenon in MOSFET circuits is more complex than described here and depends on various device and circuit parameters (eg, C_{gs} not just C_{gd}). Some MOSFETs are specifically designed to improve their dV/dt immunity and can help designers deal with this issue.

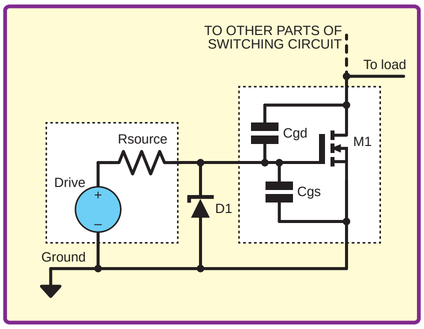


Fig.12. Zener clamp to protect MOSFET gate from dV/dt induced damage

The dV/dt spikes on the gate will be worse for higher driver source impedance, specifically the effective impedance when the driver is holding the MOSFET in the off condition. This may be poor even in a driver having the ability to provide very high currents when the transistor is switched. Thus the driver plays a key role in avoiding dV/dt-induced damage.

Zener protection

It is possible to protect the gate by adding a suitable Zener diode between source and drain, as shown in Fig.12. The Zener will clamp positive-going voltages below the maximum allowable gate voltage, but will not prevent unwanted turn-on. The Zener will also clamp negative-going spikes on the gate because it will enter forward conduction. The Zener is not as good a solution as using a better driver and/or MOSFET, and it may cause instability in some situations.

The discussion on the *Chat Zone* about ***miketuk's*** damaged FETs indicated that dV/dt-induced gate damage may have been the cause and a Zener clamp at the gate may have solved it, but we cannot be completely certain about this. This article has covered some of the mechanisms whereby power MOSFETs are damaged during operation, but it has not addressed all the potential issues. Further details can be found in technical articles published by device manufacturers such as Texas Instruments, NXP, Analogue Devices and International Rectifier and various other sources.

MAKE YOUR OWN PCBs

Part 4

Mike Hibbett looks at how to produce your own printed circuit boards (PCBs). In Part 4 he looks at outsourcing the manufacture of a complex design.

IN this final article in the series we look at designing a more complicated board than last month, one which we must send out to a PCB manufacturer rather than etch ourselves. Just like last month, we are going to create a panel of boards, but the 'panellisation' will be the manufacturer's problem, not ours. We only need to create a single board design. The board is *much* more complicated than last month; it has copper tracks on both sides – a double-sided design – and uses surface-mount components. It has an interesting mix of technologies too, a combination of surface-mount ICs, through-hole connectors, surface-mount connectors and even an old-fashioned potentiometer. We will end up with a few wires, but nowhere near as many as on the prototype shown in Fig.1.

Since no schematic existed for the prototype – as you might guess from Fig.1, it was cobbled together section by section – the EagleCAD schematic has to be drawn by disassembling the prototype and tracing the wires. This was a job almost as hard as putting it together in the first place. And of course, as I dismantled the box to view the underside, bits started falling off and breaking. Oh, if only I had drawn it in EagleCAD first! You can see the schematic I (eventually) created in Fig.2.

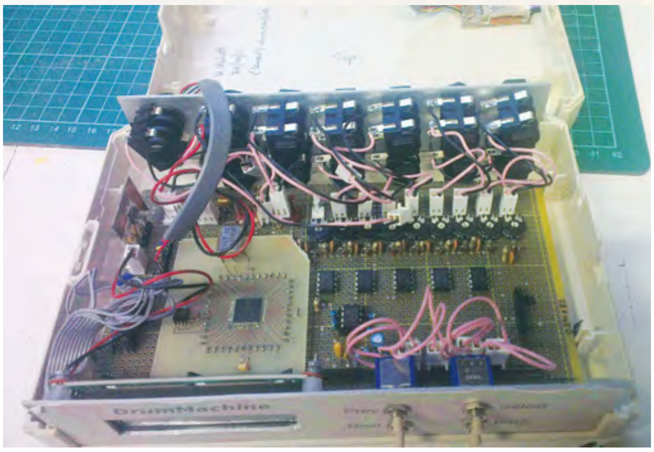


Fig.1. The prototype drum kit

Notice how few connecting wires there are in the drawing; we make use of a useful CAD trick – when you label a wire, it will be electrically connected to any other wire with the same name. This keeps the schematic tidy and easy to create. On designs with multi-page schematics the tools provide a search facility so you can find all references to a given wire label.

As is the norm when transferring a design to CAD, my first thought is for unusual components – the surface-mount processor, headphone, power and MicroSD card socket. Do they already exist in the standard library? Since I hadn't purchased the parts yet, I wasn't constrained to any particular part. So if I could find a symbol for a part I could purchase, I would save myself some creativity.

The card socket didn't exist, so I went online to look for one created by someone in the community – no point creating one if someone else has already done it. There was one, but it was a devil to find. It required a bit of imagination; searching the internet for 'EagleCAD microSD', then looking to see if the part I found was available for sale from Farnell or a similar supplier. I Eventually found a library called **con-3m-new.lbr**, released in the public domain, containing a symbol for the 3M part 2908-05WB-MG. Farnell do not stock this part, but a search for the number on their site brought up a series of parts from Molex. Odd, seeing as the part numbers were not even similar. Looking at the datasheet for one of the 3M parts, it turns out the Molex 500873-0806 part, Farnell code 1572016, shares an identical footprint. Perfect.

Adding a new part

I downloaded the file to the Eagle CAD library files directory at **C:\EAGLE-7.0.0\lbr** (on my system) and then

in the schematic window’s command line typed:

```
use *

add
```

This brought up the normal library navigation dialog, from which I was able to select the socket from the **con-3m-new** directory and drop it onto the schematic page.

Finding the processor was easier, as it is supplied by Farnell and available for download from the processor’s page on their site. Installation of the EagleCAD symbol is a little unusual; they supply an EagleCAD ‘script’ file and a **readme.txt** file. The **readme** provides a series of a half-dozen or so steps that need to be followed to create the library for the part. Why they didn’t just provide a **.lbr** file is a surprise. If they thought this would make their library ‘future proof’ they have shot themselves in the foot – CADSoft have always supported earlier libraries. Farnell’s instructions, however, were for an earlier version of EagleCAD and were simply wrong. A bit of detective work on my part (OK, guess work) got me a library, eventually. I do hope Farnell will update these installation instructions.

The Spansion Flash 32MB Flash memory IC was a bit special; it has the normal 8-pin SOIC pinout for a 25xx EEPROM device, but in a wider package – 208mils rather than the more normal 150mils. I’ve been caught out by this package before, so I’m glad I noticed. The 208mils-wide part does not exist as a selectable option in the library for a 25xx series device, so again I had to get a bit creative.

Fortunately, we can copy package symbols from other library components. A scan through the list of other 8-pin packages reveals the Maxim library has one.

Copying a library package

Back at EagleCAD’s Control Panel dialog we select **File -> Open -> Library** and navigate down to the **maxim.lbr.** Clicking on that entry opens up an empty dialog window. Click on the package icon and then scroll down and select **SO08-208** by double-clicking on it.

Click on the Layers icon and select **All**, **OK**. Then use the Group option to select all the elements of the component. Now click on **Edit -> Copy**.

Now click on **File -> Open** and select the Microchip library, which contains the 25xx part we will modify. Once the dialog opens, click on the Package icon and in the **New:** text field enter

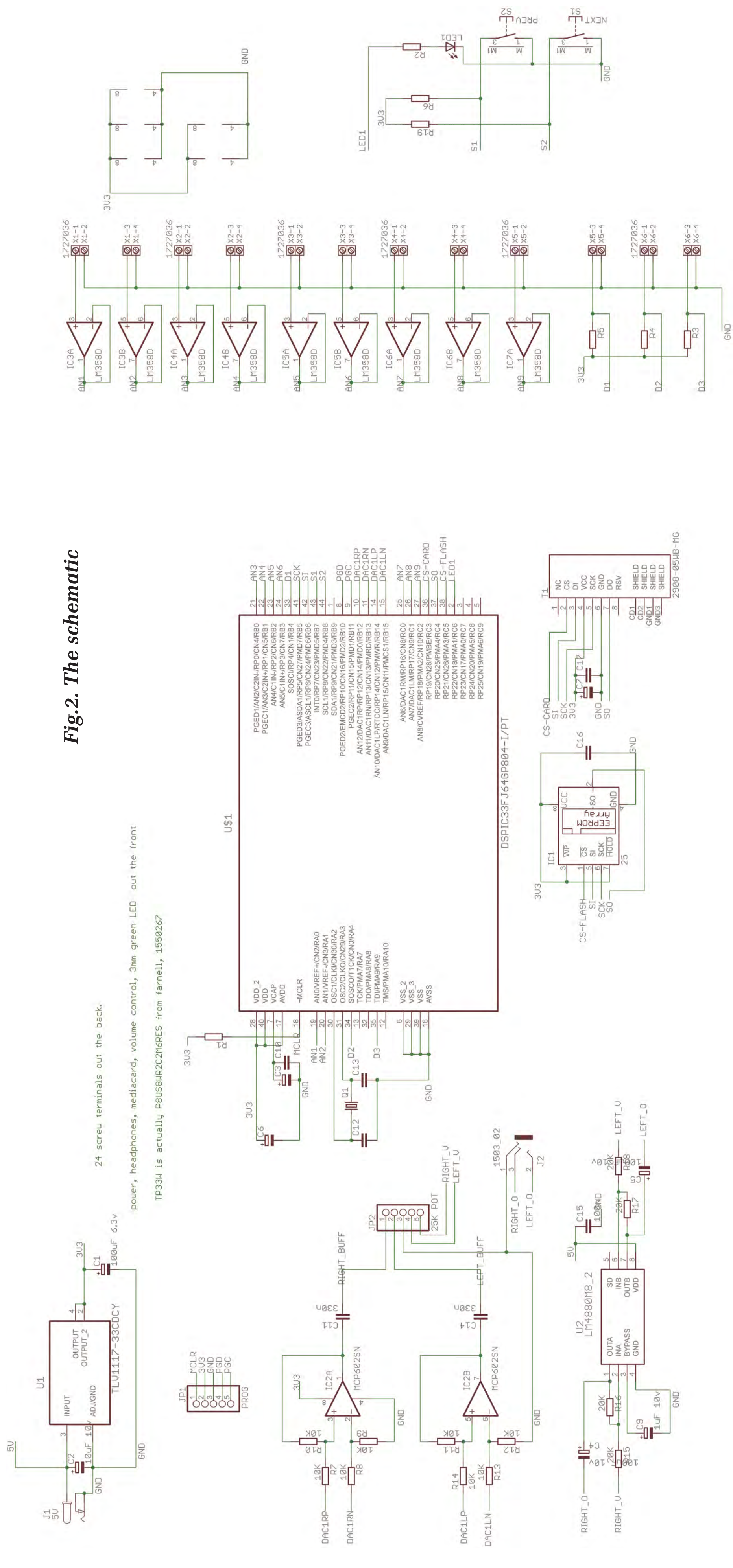


Fig.2. The schematic

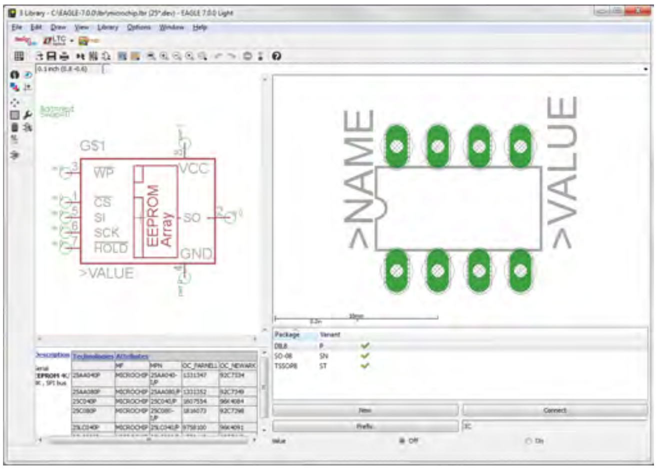


Fig.3. The device editor dialog

SO08-208, then click **OK**, **Yes**. You can now select the **Paste** option to drop the copy of the package on the screen. Position the package so it is centred on the origin, as shown by the cross hairs. Now click on the Device icon, and select **25***. The dialog shown in Fig.3 should appear.

Notice how there are three packages listed in the bottom right hand of the dialog. Let's go ahead and add ours. Click the New button, scroll down, select our **SO08-208** package and click **OK**. We now need to connect the wire on the symbol to the physical pads on the package drawing. Click the **Connect** button, and the dialog shown in Fig.4 appears showing the Pin (from the symbol) and the Pad (from the package). You click one entry under Pin, one entry under Pad and then click **Connect**. A quick examination of the Spansion Flash datasheet shows which Pin designation goes where, and we quickly end up with the table shown in Fig.5. Click **OK** when you reach this point.

Close the library, and then go back into the schematic and add the part from the Microchip library. It will be called '25' as a device, but we can change this using the Value command later, once it has been placed on the schematic.

MCP6022 op amp

Next up is the MCP6022 IC. This part is available for purchase from Farnell in a standard SO08 package. However, the part does not exist in the EagleCAD library. Another op amp does, the MCP602. The package is the same size and the pin-out is the same, so we will use that symbol instead, and simply change the name once it is placed on the schematic.

Crystal

For the microprocessor crystal we chose a cheap surface-mount version, in a HC49 base – essentially a through-hole crystal modified to be placed on the top of the board by an SMA machine. The datasheet showed the recommended board pads. I learned something about EagleCAD today; if you know the *package* you want, type the ADD command in the board window, not the schematic window. Although EagleCAD will not let you actually add a component on the board layout (reasonable, but odd that you can get this far in the first place) you can still search the library. So I searched for **HC49***, and found the package HC49UP in the Crystal library that matched the datasheet. So it's back to the schematic dialog, selecting **Add**, and then find the device in the Crystal library that has a HC49UP package.

Voltage regulator

The voltage regulator used in the original prototype was also found to have an EagleCAD symbol available at Farnell, so we copied that over as before.

LM4880 dual power amplifier

The LM4880 symbol was found on a schematic on the Internet, with instructions on how to extract the symbol provided by the author on his site. The DC jack was found on the dangerous prototypes web site **http://dangerous-prototypes.com**. It was just good luck that it is the same part as supplied by Farnell.

If this all sounds a little confusing, it isn't really – these searches took a few minutes and saved perhaps several hours effort creating them manually. In this case, we have managed to find all our parts without having to create a single device symbol. That's very rare, and has saved a few hours work. Creating symbols in EagleCAD is not exactly difficult, but if you do not plan to use the symbol more than once the effort can be a little un-rewarding. In our case, we will evaluate how well the parts work, and if we like them and expect to re-use them we will invest a little more effort in the documentation and perhaps improve the silk screen drawing.

Making sure it all fits

Purchasing the new components before sending a board design off to a manufacturer is an essential step before completing a design. On this board we discovered not only that the buttons should be placed closer to the board edge, but that the headphone socket pin-out was not as I had guessed. It's not uncommon for a datasheet to be very weak on the specifics of 'which contact means what', and there is simply no substitute for obtaining the real parts and placing them on a printout of the board design, which we did. It's not a fool-proof solution if your board has to fit in a case (I made a small error in the board design, as you will see later).

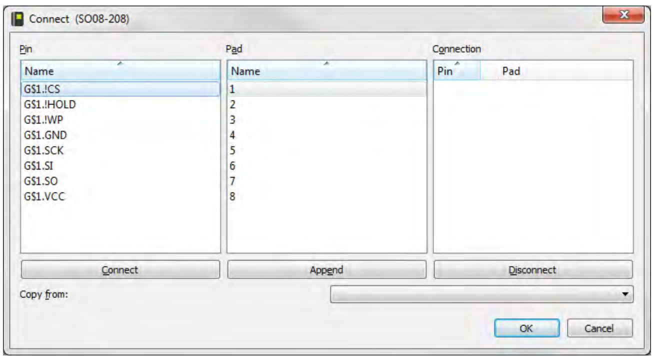


Fig.4. Connecting the symbols

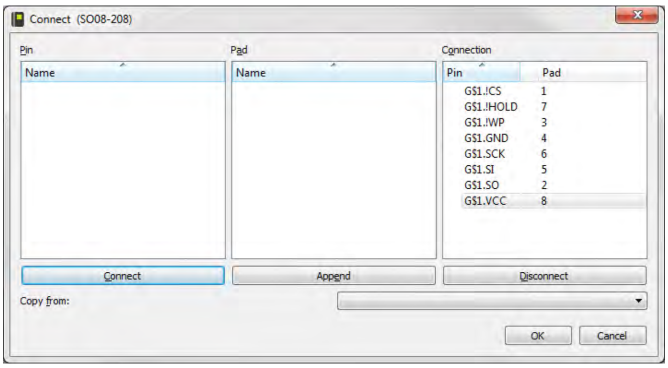


Fig.5. A fully connected package

Choosing the board shape

With the schematic entry completed, we start the board design by selecting the **generate/switch to board** icon at the top of the schematic entry window. A new dialog opens showing the outline of a rectangular board and all our components clumped together on the left-hand side, as shown in Fig.6. This stage is always the most daunting, as the mass of components and linking 'airwires' appears overwhelming. The key at this point is to remember the modular nature of the design – a microprocessor circuit, an audio amplifier, the multiple input conditioning circuits. Concentrate on placing and constructing one 'module' at a time; you can use the group move option later to reposition them.

However, before we position our components we must decide on the size and profile of the board – the two key factors driving PCB price are the number of layers and the area of the board. Other than those two design factors, the other big cost drivers are quantity and lead time. 100 PCBs ordered for delivery in a month could be cheaper than 10 PCBs ordered for delivery in five days. The significant reduction in cost for larger quantities is an indication of the amount of 'NRE' charges involved – non-recurring expenditure – relating to the setup of the job rather than the production process itself.

It's pretty clear looking at Fig.6 that we are not going to achieve this board design on a single layer PCB, so we will go with a two-layer design. Next, what board area are we going to go with?

Estimating the minimum board size is a very difficult task; too small, and you wont be able to place all the tracks required. Too large, and you waste money on PCB costs. My approach has been to start with a large board area, design each 'module' in its own part of the board, and then move the modules together, perhaps rotating groups of components by 90 degrees, until a satisfactory fit can be made – then route the final signals together.

Start with your enclosure

Another key point driving the board shape is the enclosure you put it in. We wanted a stylish enclosure, something that would look almost custom made for the job. We found a lovely two-part enclosure from OKW in the UK, as you can see in Fig.7. Purchased directly from the manufacturer's UK office, the staff were very helpful on the telephone and the delivery charge for a single case was very reasonable. If you are looking for something special for your next project, check them out at: **www.okw.co.uk**.

The inside of the case has a number of mounting holes and cut outs, which your board must conform to. A full CAD drawing is provided by the manufacturer, which you can use to design the profile of your board and any holes or slots required. This is where the fringe benefits of having the board professionally produced come in to play. To cut your board from the PCB panel, a manufacturer uses a router cutter. The nice thing is, it's computer controlled, and really doesn't care what the profile looks like. It will just follow the board profile you draw in EagleCAD. So a complex profile, as you can see in Fig.8, adds nothing to the cost (likewise, with the large holes for the pillars to pass through). Cutting such profiles by hand would be *very difficult indeed*.

Fig.7. The drum kit enclosure

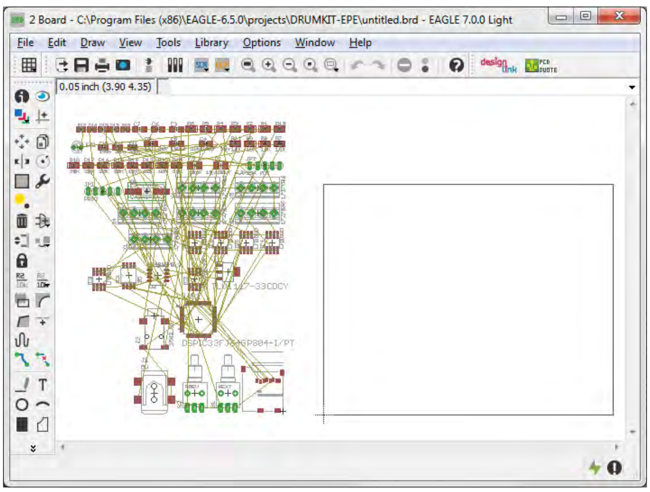


Fig.6. The initial board editor view

It's important to understand the processes and tools a PCB manufacturer uses when creating boards, as this can have an effect on your design. For example, looking at my board CAD image in Fig.8, notice how in the top-left corner I have 90-degree angles. On the manufacturer's board the external right angles will be perfect, but the internal right angle will have a radius – this is because the cut is being made with a router drill bit, which has a natural radius, probably 2-5mm size. If you really need a perfect right angle, then talk to your PCB supplier. Alternatively, ensure that you can accommodate a 3mm radius on internal angles.

Wiring it all up

With the PCB outline modified to match the profile of our enclosure, the next step is to place the components. As mentioned before, it's a good idea to position these components in their logical 'module' groups. I started by placing the drum pad input edge connectors, then the op amp conditioning circuits (multiple copies of the same simple circuit) then the 3.3V regulator circuit, followed by the audio amplifier, and finally the microprocessor circuitry. The components all go on the top layer. Try to avoid placing components on the underside; it can cause problems if you want a company to assemble the board for you, and also complicates fitting a board into an enclosure.

Routing of the signals was done by first manually routing the power signals (always the most important) then routing the audio and finally the digital signals. Here is a tip: save your design, then run the auto router. Look at the resulting routing. If you like some of the suggestions, go back to your saved design and add those back in manually. Then repeat the process. I sometimes move components around, let the auto router run and assess the efficiency of the component placement by how many via holes were needed. This was repeated until a low number of via holes was reached. Then, the signals were ripped up, and the wire routed manually. The auto router is useful, but will not produce the best routing. You always have to do this by hand.

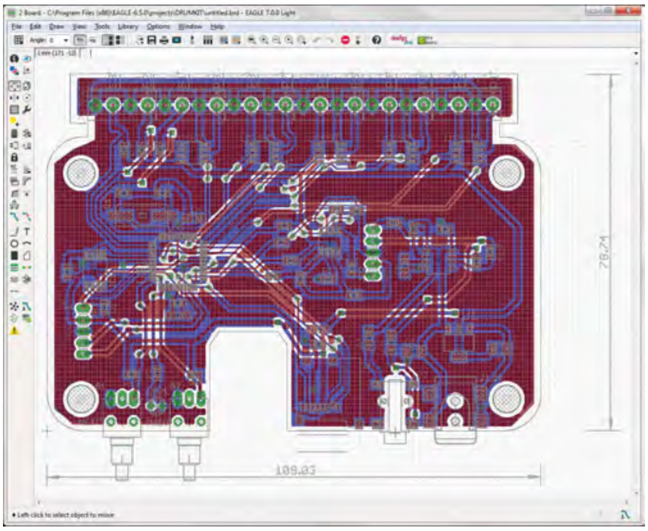


Fig.8. The board design

Creating the wire links between the chips is not easily described, and is hardly a spectator sport. However, if you would like to see me routing the tracks on a PCB in EagleCAD, I have created a YouTube video that is available here: **http://goo.gl/Bo4tZ6**

Board manufacture

It's generally a good idea to select a PCB manufacturer *before* laying out the board, because different manufacturers have different manufacturing process limits. For example, the gap between a copper track and the edge of the board, or the thinnest track they can support. Some manufacturers can supply a design rules file that can be imported by EagleCAD, and the design limits are checked automatically. Some will just go and merrily modify your design to suit their needs without telling you. The moral of the story is: know your board manufacturer. Don't be afraid to email them, asking questions. They want your designs to work, because it will mean future business.

I chose Beta Layout in Ireland to manufacture the board because they were local, but also because they set themselves up originally to provide services to hobbyists and very low volume manufacture. They would take your design, add it with several others and create them on a single panel. I had several email and telephone conversations with them about the design of the board; questions that were quickly and politely answered. One of the nice features of their process is that during manufacture they send you a webcam image of the boards progress through the factory. When you are using a low-cost, several-week delivery option, this can give great feedback that things are happening. It can also indicate if things are going wrong (although cancelling an order mid-production may save you no money, it will save you time.)

You can see the four boards returned in Fig.9. I simply asked Beta Layout to make the board up in a 2 × 2 panel, with a solder stencil. They derived the information necessary from the EagleCAD data I supplied. Having received the boards, the first thing to do was to check that all the specialised components fitted – which they did, as you can see in Fig.10. The next test, which won't happen until I've SMA soldered the components, is to see if it fits well in the enclosure. But that is for another day!

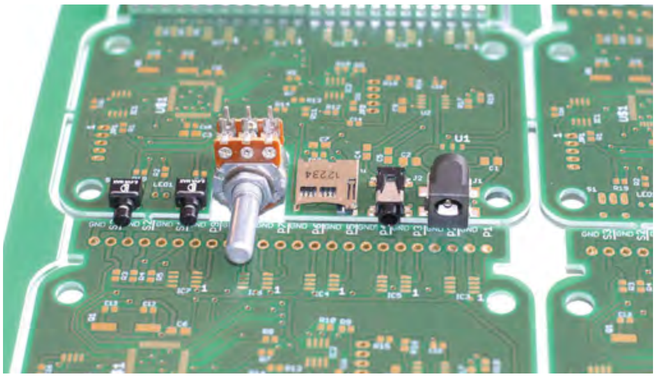


Fig.10. Checking special components fit. They do!

The choice of the drum kit PCB was no accident; I do intend to use these boards as the second prototype for my open-source drum kit design. Check out my *Pic 'n Mix* column over the coming months where I will report on progress with the build.

I hope you have enjoyed this introduction to PCB design and manufacture, and that it will inspire you to try a more ambitious design yourself. And remember, PCB manufacturers are happy to answer your questions; the hobbyist market is an important and growing part of their business. Now, where did I put my drumsticks?!

Our thanks go to CadSoft for loaning us a licence for EagleCAD and to Beta Layout for supplying the boards and stencil for this month's design. Robert Keating in particular has been very patient answering my many questions. This article series would not have been possible without their support.

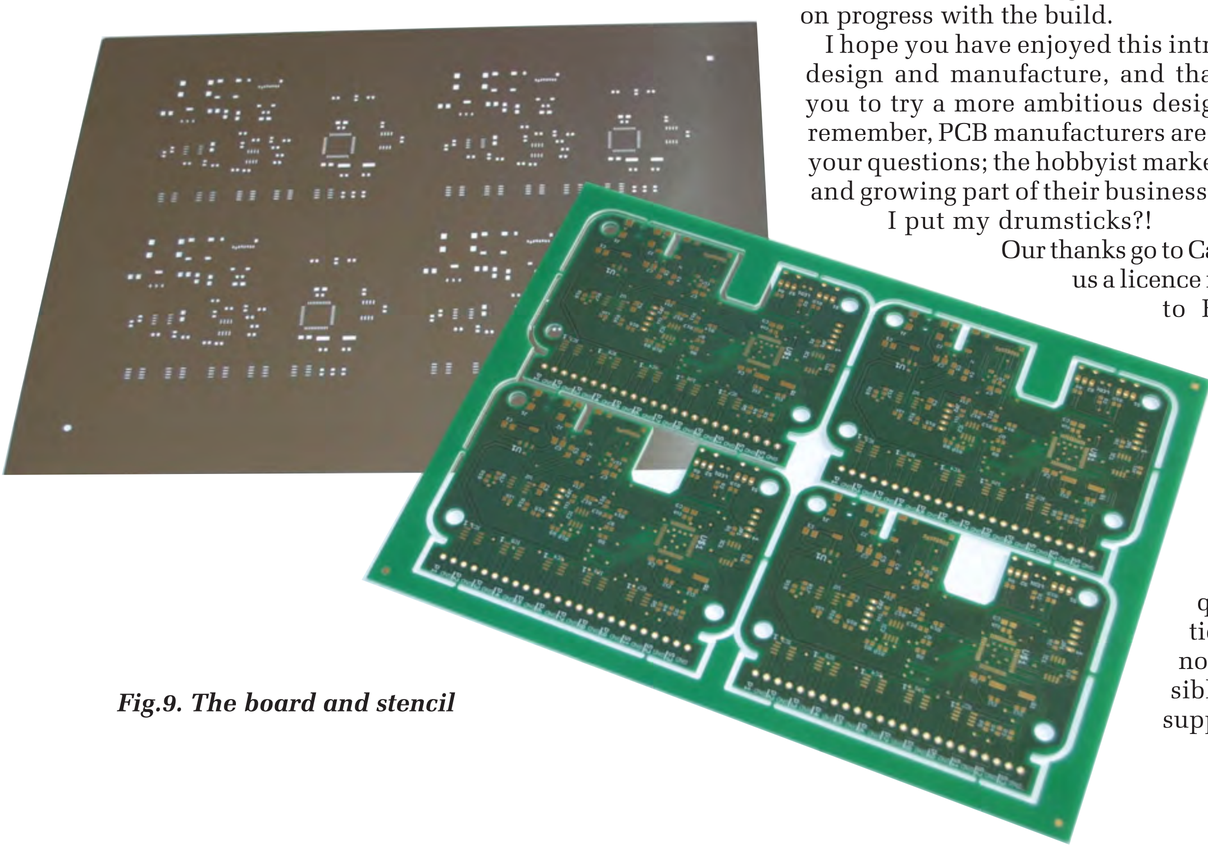


Fig.9. The board and stencil

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Fine-tuning our ADC skills

THIS month, we'll equip our development board with an analogue input, and add the software to operate it in our template code. The hardware to demonstrate it is very simple – we've only added a trimpot resistor to the previous hardware set-up where we added a cheap graphics LCD. You can see the set-up in Fig.1, and the circuit diagram in Fig.2.

We discussed the differences between analogue and digital input ports last month, but one question that wasn't answered is: 'Are there any special requirements for the signal that drives the analogue input pin?' The answer, unfortunately, is 'Yes'.

Input signal requirements

Digital inputs on processors running at 3.3V view the entire voltage range between 0V and 3.3V as one of only two values, zero (for voltages close to 0V) and one (for voltages close to 3.3V.) With such a wide gap between the two extremes, a small amount of noise on the signal will not be detectable. Analogue inputs on the other hand divide the same voltage range into 2^10 or 1024 values (in our ten-bit example).

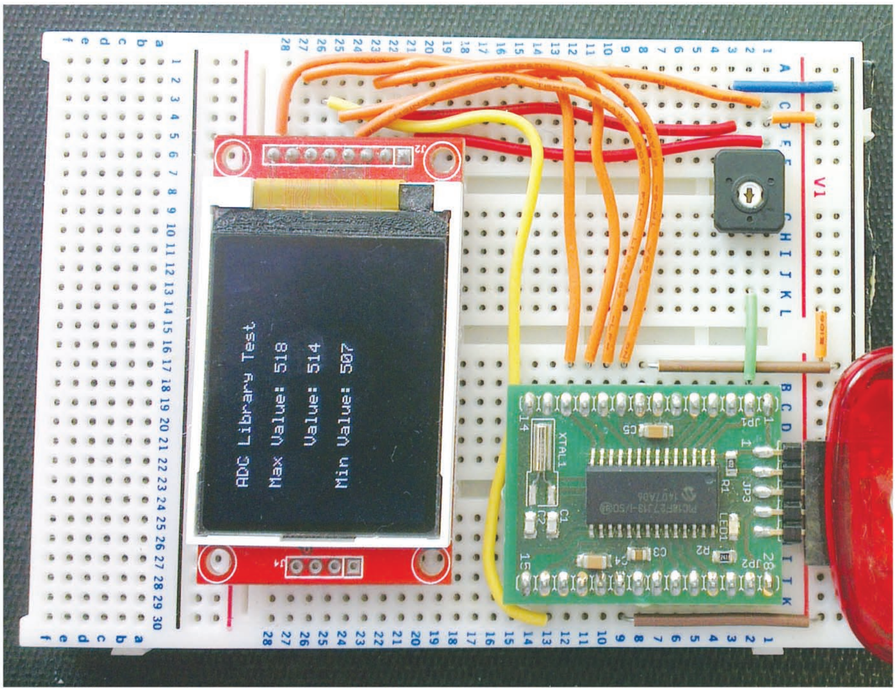


Fig.1. ADC test circuit set-up

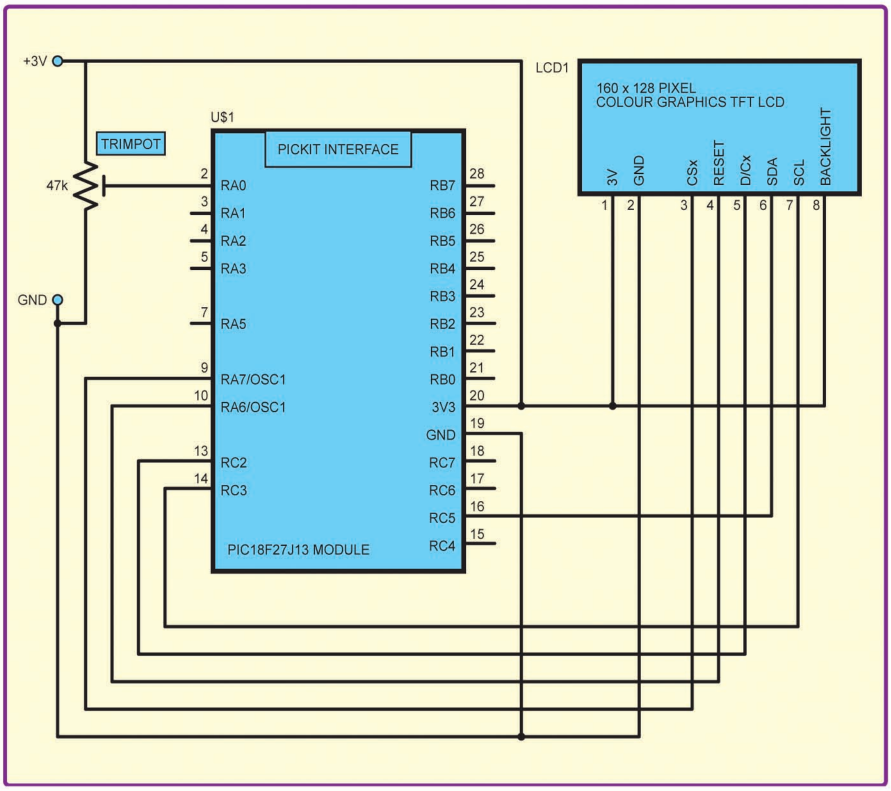


Fig.2. ADC circuit diagram

That's about 3mV per step, so a small amount of noise will be detectable as a fluttering up and down, perhaps by a few values, of the conversion value. You need to keep your signals as clean of noise as possible in these situations. That means short wires, good grounding, decoupling and filtering as and where necessary.

The filtering doesn't have to be done only in hardware – you can also filter noise out by taking several samples and averaging the result. How much effort you employ will depend on what you are trying to achieve, and how quickly you need to sample the signal. If the rate at which you need a reading is slow enough, say ten times a second, then you can easily 'over-sample' the input signal and filter it digitally. The filtering algorithm can range from the simple: 'add all the samples and divide by the number of samples', to more complex signal processing techniques. You can also add each sample to a running total, providing a new averaged value on each sample.

It's also important to try to make the input signal impedance as low as possible. If your signal's impedance is high, say tens of kΩ and above, then the input characteristics of the analogue-to-digital converter may

load the signal, changing what is being measured. Remember the input signal must charge the ADC's sample capacitor up to the same level as itself, and in a very short period of time (the 'sample time' of the ADC.) The higher the source impedance, the larger the RC time constant and the longer it will take to charge. If in doubt, add a buffer stage such as an op-amp between your signal and the CPU.

And finally – as we mentioned last month – keep the power supply rails to the processor as clean as possible. This applies to the reference input voltage in particular (either the main CPU supply rail, Vdd, or the Vref+ input if used.)

Selecting the input pin

The analogue inputs are multiplexed with normal digital I/O pins, and on power-up the analogue mode is selected by default. It's an oft-heard cry on the Internet – 'Why is my digital pin not toggling?', to which the answer is invariably: 'Have you set your pins to digital I/O?'. While normally a pain, this month the default settings work in our favour. By now you may have worked out why the default should be analogue – because any circuit that drives a pin to mid-rail, expecting it to be an analogue pin, would cause an excessive amount of current to flow while the pin is configured in digital mode. Left long enough, it could damage the chip. The moral of the story is, if you have an analogue signal on a pin, make sure that pin is configured as an analogue input – and that it stays that way.

Library functions

The ADC is a complicated peripheral – but fear not! – Microchip have extended the standard C library with additional functions available through their own 'PIC18 Peripheral Library'. This library is a set of C language functions, used just like the standard C library, specifically designed to handle our chip's peripheral circuits and to make our life easier.

Unfortunately, *finding* the details of the Peripheral Library is not easy, and I spent an 'amusing' half hour locating and then making sense of the documentation. You start by running MPLAB-X, opening a project (like the template code) and then clicking on the 'Dashboard' tab in the main window, as shown in Fig.3. Click on the 'Help' icon, as shown in the figure, and a Web page will open in your web browser, displaying a list of documents. The *8-Bit Peripheral Libraries* Manual is the final entry on the page.

On opening the *Manual*, you find yourself presented with an ominous 1300-page document. Fortunately, it covers all Microchip 8-bit processors, so there is a lot of irrelevant and duplicated information. It's not an easy document to navigate. You scroll down the index to find a reference to the processor we are using, the PIC18F27J13. That sends you off to page 42, which then immediately sends you off to page 287. That page starts referring to the '2xJ53 Set'.

What's that?

Although the document doesn't make it clear, the PIC18F27J13 is a member of the 2xJ53 family and they share the same peripheral definitions. And 'hey presto!', the ADC module is the first peripheral mentioned. There are just seven functions mentioned, as detailed in Fig.4. Once again, we are directed off to another part of the document for the description of the functions.

The details provided are a little thin, to say the least. The parameter values are stated, but not explained. There is no explanation of the *sequence* in which these functions need to be called, or how the correct parameter values are arrived at. Only a single example is shown. Clearly, we need to study the datasheet in more detail to work out how to use this module. The library documentation is not going to be sufficient.

What we can do, however, is start to create our own ADC library, adding the code into the template. Once again, we work by initially creating a simple test application. The library code, when not referenced by your own application, will not be included in the final application.

Putting it together

So what are we doing? We are taking the function calls provided by Microchip in their library and placing them into our template source code files, suitably commented so as to be easily used. This is the difference between a good library and a good template – even a clearly documented library only tells you *what* you can use, not *how* to use them. A template source file puts those functions together in the context of an actual application, which helps with understanding and makes creating you own programs just that little bit easier. And with the ADC peripheral, we need all the help we can get!

Remember, when we add the code to our library, it will not automatically increase the size of an existing application. Only functions that you actually refer to (directly or indirectly) will be included in your code.

Adding new files

So, let's start by creating the new library files. We are going to add two: **lplc-adc.c**, to hold the source code, and **lplc-adc.h**, which is the header file you will include in your own **.c** files when you want to use ADC functions. It acts at the specification of the ADC library's 'Application Programming Interface'. In theory, if we write this library correctly, you will never need to look at the contents of **lplc-adc.c**. The header file provides all the information we need to use it. This way, we can change **lplc-adc.c** later on without needing to modify our applications that refer to it. This is called 'abstraction', where we avoid needing to understand the lower level details of a library.

To add a file you right-click on the project name in the project navigation window, select 'New' and then 'C Source File...' as shown in Fig.5. At the dialog that appears, simply type `lplc-adc` and click on 'Finish' – the dialog fills in the other details, and creates the file in the project directory. As the file is a **.c** file it is added to the build process automatically; we don't need to tell the IDE to add it. You can repeat the same exercise for **lplc-adc.h**, selecting 'C Header File.'

We can now add some functions. We are going to start with a simple yet functional implementation:

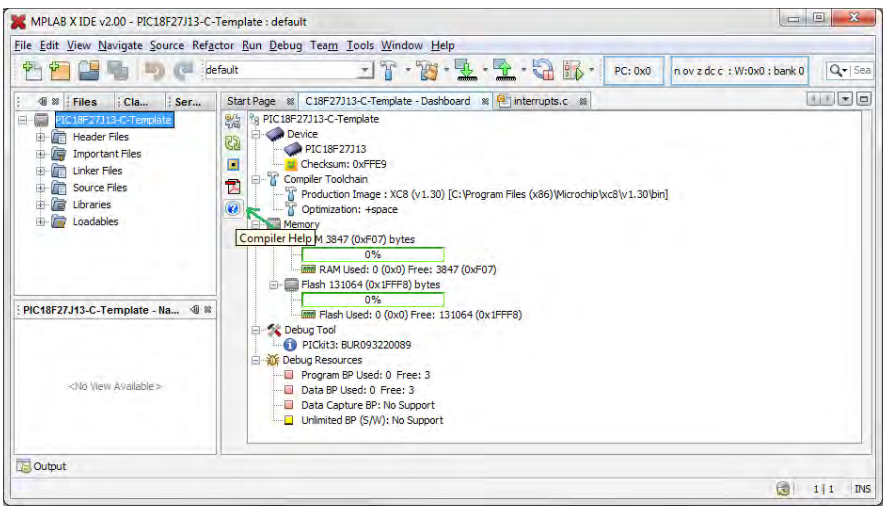


Fig.3. Accessing the compiler help system

Functions
OpenADC (see page 873)
SetChanADC (see page 882)
SelChanConvADC (see page 889)
ConvertADC (see page 896)
BusyADC (see page 897)
ReadADC (see page 897)
CloseADC (see page 897)

Fig.4. ADC library functions

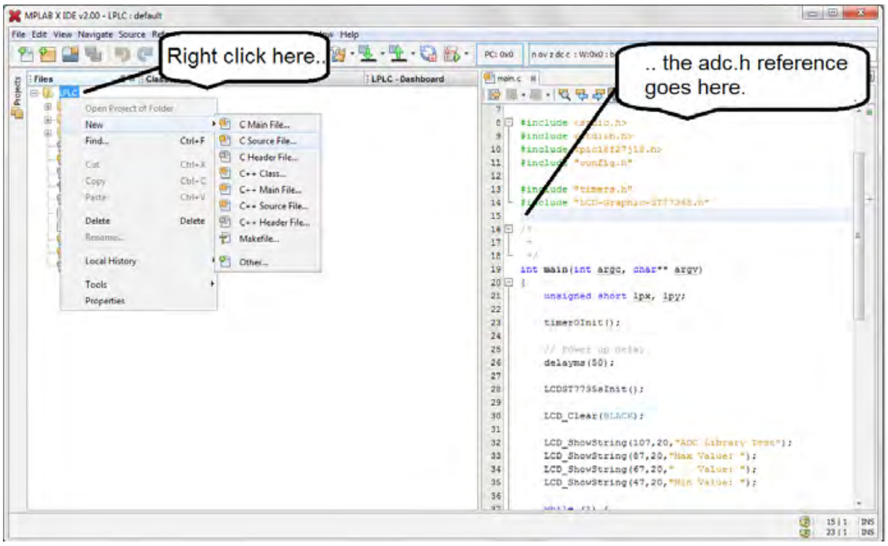


Fig.5. Adding new files

```
adc_int(param1, param2, param3, param4)

convert_adc(void)

busy_adc(void)

close_adc(void)
```

This is a simple, blocking implementation (based on the example in the Microchip documentation) that enables a single input at a time. We'll expand it further next month, but for now lets look at what the functions do.

`adc_int(parameter list)` – this function is (currently) a wrapper for the `OpenADC` function in the Microchip library; `param1` is used as the value for the register `ADCON1`, and `param2` for `ADCON0`. `param3` specifies the ADC trigger option register `ADCTRIG`, and `param4` specifies the particular ADC input you wish to use.

`convert_adc` – this instructs the ADC peripheral to start a conversion. This is a non-blocking call and will return quickly. The ADC module will, however, continue with the conversion process in the background – you use the **`busy_adc`** call to determine whether the conversion has completed. Conversion can take a few tens of microseconds to tens of milliseconds.

`close_adc` – this turns off the ADC module, conserving a little power.

As we are (currently) simply re-using the libraries ADC functions we will re-use the `param1`, `param2`, `param3` and `param4` constants, as defined in the Microchip header **`adc.h`**. We've added a reference to this file in our header file, so you don't need to.

The example program included this month displays the value read back from analogue input pin AN, to which a 47k trimmer potentiometer has been connected. The trimpot is connected across the power rails, so it acts like a variable voltage source. The LCD displays the range of values recorded, which makes for an interesting observation of noise on the input signal. Put a capacitor across the potentiometer and see if it makes any difference. Then add capacitors of various values (1n, 100n, 10μF for example) between the AN input and ground to see what effect that has. It will be striking.

The code and example project are available for download from the magazine website as normal at this month's issue page under **www.epemag.com/projects.html**

The benefits of adding familiarity with ADC to one's skill set are significant. ADCs can be used to monitor real-world scenarios such as temperature, sound level, voltages and current. You can measure the health of the microprocessor's own power source and even connect a potentiometer to an ADC input to provide an analogue user interface. The possibilities are endless. And with multiple input channels available you can make use of many different techniques in a single application.

Book review

I had the opportunity to review Lucio Di Jasio's latest book this month, *Graphics, Touch, Sound and USB. User Interface Design for Embedded Applications*.

Lucio has written several books on the PIC range of microcontrollers and I'm a great fan of *Learning to fly the PIC32* and similar titles that focus on a single microcontroller. The PIC24 and PIC32 devices are very complex, and deserve their own book. Lucio does a great job and gives some interesting examples to experiment with. Like me, Lucio enjoys squeezing the most out of his processors, and his enthusiasm is infectious. This book is slightly unusual in that it covers two different topics: the MikroElektronika PIC24 Mikromedia Board and the Microchip MLA, the huge, free library of software for the PIC range of processors.

The Mikromedia board is one of a range of impressive development boards created by MikroElektronika in Serbia. At about 90 euro it's not cheap, but it is packed with well engineered goodness – a 3.2-inch colour LCD, touchpad, stereo audio codec, accelerometer, MicroSD card socket, host USB, device USB interface and a lithium polymer battery charger to enable portable applications. So it's not only a great platform for experimenting with new protocols and interfaces, but its possible to make a standalone, completed project.

In the book, the board serves as the experimental platform for exploring the Microchip MLA codebase, and that is what the book really addresses – practical application of the MLA libraries.

I quite like this approach; I've used the MikroMedia board before, but with the MikroElektronika development environment, not Microchip's. I'm a fan of the MPLAB-X/PicKit3 toolchain and as I had not yet played with the MLA (I've used it's predecessor, however) it was a great opportunity to learn something new.

The book's topics break down into the following areas: graphics, touch input, MicroSD card data storage, sound generation, advanced graphics and USB interfacing.

The USB interfacing section has the best introduction to the subject that I have come across, and I learned a few new things myself.

It's just 270 pages long, but the subject is presented in a clear, concise yet understandable format, which will be relevant to anyone moving onto the PIC24 or the MLA from other processors. The reader is expected to be familiar and comfortable with the 'C' programming language, as Lucio does not waste time trying to pad his work out with unnecessary introductory text. If you are new to 'C' or embedded software, find yourself some other books too – but still get this one, as it's a gem.

Kickstarter

By the time this issue comes to print my second Kickstarter project, the LPLC TOO, will have completed its campaign (and be either a resounding success or total failure. There is no in-between with Kickstarter.) This board is a tiny version of the LPLC, measuring just 20mm × 6mm and 1.5mm thick. It's designed for those hard-to-reach problems such as wearable sensors and general 'Internet of Things' applications. You can find the project via a search for 'LPLC TOO' on **kickstarter.com** or at **mjhdesigns.com**, where I will be hosting the technical data.

Next month

Next month, we'll tie up the loose ends of the ADC module, adding interrupt handling and working through the mathematics of how to choose an appropriate ADC clock and sampling time.

*Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at **@MikeHibbett**, and from his blog at **mjhdesigns.com***

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KINDLE FIRE HDX EXPLAINED

This book is written to help users get to grips, quickly and easily, with the amazing Kindle Fire HDX tablet. You will be guided through the configuration and use of the Kindle Fire HDXs facilities and functions. This book was written using the 7" HDX but it is also applicable to the 8.9" model.

Among the many topics covered are: An overview of the Kindle Fire HDX. Charging and setting up, connecting to a Wi-Fi network, registering the device and connecting to Social Networks; setting up and using the 1-Click Amazon account for buying and downloading books, music and other content that you have searched for. Explaining the use of the Carousel. Starting screen Apps. Web and Device settings and the Mayday facility; browsing the web with Silk Internet explorer, using Bookmarks and History, printing web pages, documents and messages; connecting to a server to send and receive e-mail messages, using and saving attachments. Creating and organising your Contacts and Calendar appointments; using the Kindle Fire camera to take photos and videos. Watching TV, listening to music you bought, imported and from the radio. Using the X-ray feature with books and other media; Using the OfficeSuite to view your documents, upgrading to OfficeSuite Professional 7 to allow both viewing and creation of Word documents. Excel spreadsheets and PowerPoint presentations. And more besides...

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WINDOWS 8.1 EXPLAINED

Windows 8.1 is the latest version of Microsoft's operating system. It is installed on all new Windows Desktop. Laptop and X86 tablet computers and is also available as a free upgrade. Whether you choose to use the touch screen Tile interface or the mouse operated Desktop interface, a good working knowledge of the operating system is essential to get the most from your computer and this book will help you to do just that.

The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

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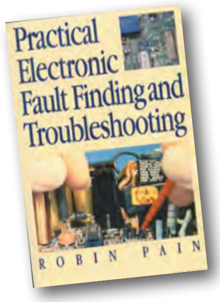

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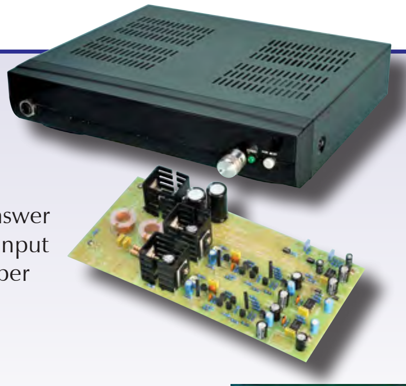
Next Month



"Tiny Tim" Stereo Amplifier – Part 1

Most TVs have mediocre sound quality; so how do you get better sound? The short answer is that you need a good quality stereo amplifier with either a Toslink or S/PDIF digital input and some decent speakers. Our solution next month is the 'Tiny Tim', featuring 10W per channel of amplification and digital inputs.

PortaPAL-D – Part 2

In the second part of our new go-anywhere Portable PA system, we put together all the electronics. There's a lot to it, but we've separated out each section to simplify matters. Lots to look forward to next month!

SiDRADIO – Part 4

Have you wondered if there's anything else you can do with your SiDRADIO set-up using a DVB-T dongle – besides receiving AM, NFM, WFM, CW, SSB and DRM? Other applications are becoming available all the time. Already there's one that lets you receive DAB+ digital radio and another to receive some of the many different types of narrow-band digital mobile radio (DMR).

Introducing the Raspberry Pi B+

EPE's resident Raspberry Pi expert, Mike Tooley, takes an in-depth look at the recently introduced Raspberry Pi model B+ which aims to put right many of the shortcoming of its predecessor, the Raspberry Pi Model B. So, is this really something to shout about or is it just more of the same? All will be revealed next month.

JANUARY '15 ISSUE ON SALE 4 DECEMBER 2014

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